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[Document Name] CLAIMS

[Claim 1]

A moving picture encoding method for performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that:

5           the method includes, in reference frames used for the multi-frame motion prediction, a frame that has been encoded in a higher picture quality than the other frames of the same picture type.

[Claim 2]

10           The moving picture encoding method according to claim 1, characterized in that the frame encoded in the higher picture quality is a frame to which more code amount is assigned than the other frames of the same picture type.

[Claim 3]

15           The moving picture encoding method according to claim 1 or 2, characterized in that the frame encoded in the higher picture quality is a frame having a smaller quantizing parameter than the other frames of the same picture type.

[Claim 4]

            The moving picture encoding method according to any one of claims 1 to 3, characterized in that the frame encoded in the higher picture quality is a P-picture frame.

[Claim 5]

20           The moving picture encoding method according to any one of claims 1 to 4, characterized in that the frame encoded in the higher picture quality is a B-picture frame.

[Claim 6]

25           The moving picture encoding method according to claim 5, characterized in that, in comparison with a final B-picture frame in the continuous B-picture frames, a B-picture frame prior to the final B-picture frame is encoded in the higher picture quality.

[Claim 7]

            The moving picture encoding method according to any one of claims 1 to 6, characterized in that the frames encoded in the higher picture quality are arranged at constant frame intervals.

30           [Claim 8]

            The moving picture encoding method according to any one of claims 1 to 7, characterized in that a frame interval of the frames encoded in the higher picture quality is adaptively changed in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[Claim 9]

A moving picture encoding apparatus for performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that the apparatus comprises:

5 encoding means for encoding at least one frame in a plurality of reference frames in a higher picture quality than the other frames of the same picture type.

[Claim 10]

The moving picture encoding apparatus according to claim 9, characterized in that the encoding means assigns more code amount to a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

10 [Claim 11]

The moving picture encoding apparatus according to claim 9 or 10, characterized in that the encoding means sets a smaller quantizing parameter for a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[Claim 12]

15 The moving picture encoding apparatus according to any one of claims 9 to 11, characterized in that the encoding means encodes a P-picture frame in the higher picture quality.

[Claim 13]

The moving picture encoding apparatus according to any one of claims 9 to 12, characterized in that the encoding means encodes a B-picture frame in the higher picture quality.

20

[Claim 14]

The moving picture encoding apparatus according to claim 13, characterized in that, in comparison with a final B-picture frame in the continuous B-picture frames, the encoding means encodes a B-picture frame prior to the final B-picture frame in the higher picture quality.

25 [Claim 15]

The moving picture encoding apparatus according to any one of claims 9 to 14, characterized in that the encoding means arranges the frames encoded in the higher picture quality at constant frame intervals.

[Claim 16]

30 The moving picture encoding apparatus according to any one of claims 9 to 15, characterized in that the encoding means adaptively changes a frame interval of the frames encoded in the higher picture quality in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[Claim 17]

A moving picture encoding program causing an information processing apparatus to execute encoding by performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that:

the moving picture encoding program causing the information processing apparatus to  
5 execute a process of:

encoding at least one frame in a plurality of reference frames in a higher picture quality than the other frames of the same picture type.

[Claim 18]

The moving picture encoding program according to claim 17, characterized in that the  
10 moving picture encoding program causes the information processing apparatus to execute a process of assigning more code amount to a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[Claim 19]

The moving picture encoding program according to claim 17 or 18, characterized in  
15 that the moving picture encoding program causes the information processing apparatus to execute a process of setting a smaller quantizing parameter for a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[Claim 20]

The moving picture encoding program according to any one of claims 17 to 19,  
20 characterized in that the moving picture encoding program causes the information processing apparatus to execute a process of encoding a P-picture frame in the higher picture quality.

[Claim 21]

The moving picture encoding program according to any one of claims 17 to 20,  
25 characterized in that the moving picture encoding program causes the information processing apparatus to execute a process of encoding a B-picture frame in the higher picture quality.

[Claim 22]

The moving picture encoding program according to claim 21, characterized in that the  
moving picture encoding program causes the information processing apparatus to execute a process of, in comparison with a final B-picture frame in the continuous B-picture frames,  
30 encoding a B-picture frame prior to the final B-picture frame in the higher picture quality.

[Claim 23]

The moving picture encoding program according to any one of claims 17 to 22,  
characterized in that the moving picture encoding program causes the information processing  
apparatus to execute a process of arranging the frames encoded in the higher picture quality at

constant frame intervals.

[Claim 24]

The moving picture encoding program according to any one of claims 17 to 23, characterized in that the moving picture encoding program causes the information processing  
 5 apparatus to execute a process of adaptively changing a frame interval of the frames encoded in the higher picture quality in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[Claim 25]

A moving picture data input/output apparatus to/from which moving picture data  
 10 encoded by performing a multi-frame motion prediction with reference to a plurality of picture frames is input or output, characterized in that:

the moving picture data which is input or output includes, in reference frames used for the multi-frame motion prediction, a frame encoded in a higher picture quality than the other frames of the same picture type.

[Claim 26]

The moving picture data input/output apparatus according to claim 25, characterized in that the frame encoded in the higher picture quality in the motion picture data is a frame to which more code amount is assigned than the other frames of the same picture type.

[Claim 27]

The moving picture data input/output apparatus according to claim 25 or 26, characterized in that the frame encoded in the higher picture quality in the motion picture data is a frame having a smaller quantizing parameter than the other frames of the same picture type.

[Claim 28]

The moving picture data input/output apparatus according to any one of claims 25 to  
 25 27, characterized in that the frame encoded in the higher picture quality in the motion picture data is a P-picture frame.

[Claim 29]

The moving picture data input/output apparatus according to any one of claims 25 to  
 30 28, characterized in that the frame encoded in the higher picture quality in the motion picture data is a B-picture frame.

[Claim 30]

The moving picture data input/output apparatus according to claim 29, characterized in that, in the motion picture data, in comparison with a final B-picture frame in the continuous B-picture frames, a B-picture frame prior to the final B-picture frame is encoded in the higher

picture quality.

[Claim 31]

The moving picture data input/output apparatus according to any one of claims 25 to 30, characterized in that, in the motion picture data, the frames encoded in the higher picture  
5 quality are arranged at constant frame intervals.

[Claim 32]

The moving picture data input/output apparatus according to any one of claims 25 to 31, characterized in that, in the motion picture data, a frame interval of the frames encoded in the higher picture quality is adaptively changed in accordance with differential information and  
10 motion information between a reference frame and a subject frame to be encoded.

[Document Name] DESCRIPTION

[Title of Invention] Moving picture encoding method, apparatus and program

[Technical Field]

[0001]

5           The present invention relates to a moving picture encoding technique, and in particular relates to a moving picture encoding method, apparatus and program for performing a multi-frame motion prediction, and an input/output apparatus to/from which moving picture data encoded by the encoding method and apparatus is input or output.

[Background Art]

10       [0002]

          Figure 1 is a block diagram showing a configuration of a conventional typical encoder for encoding a moving picture signal. The encoder shown in Fig. 1 includes a local decoding apparatus, and is made up from frequency convertor 101, quantization unit 102, variable length encoder 103, dequantizer 104, inverse frequency convertor 105, frame memory 106, intra-frame predictor 107, motion compensator 108, motion estimator 109, buffer 110, and code amount controller 111.

[0003]

          An input picture frame is fed into the encoder and is divided into a plurality of blocks. A predicted value by an intra-frame prediction or an inter-frame prediction is subtracted from the divided block. Here, the intra-frame prediction is a technique for predicting a current picture by using a reconstructed area of the current frame to be encoded, and the inter-frame prediction is a technique for predicting a current picture by using a picture frame that is previously reconstructed. The picture block in which the predicted value by the intra-frame prediction or the inter-frame prediction is subtracted is called a prediction error.

25       [0004]

          Incidentally, a picture frame encoded by applying the intra-frame prediction to all blocks in a current frame to be encoded is called an I-picture. A picture frame coded by using both the intra-frame prediction and the inter-frame prediction is called a P-picture. Further, in the inter-frame prediction, a picture frame coded by referring to a plurality of picture frames, which are input before and after the current encoded frame, is called a B-picture.

[0005]

          Generally, I-pictures are set at constant intervals, and a section that is separated by the I-picture and includes a plurality of frames is called a GOP (Group Of Picture). Definitions of the I-, P-, and B-pictures and the GOP are stipulated by the MPEG which is the moving picture

encoding standard in the international standardization.

[0006]

Then, the above prediction error is converted into a frequency domain by frequency  
 convertor 101. The prediction error converted into the frequency domain is quantized by  
 5 quantizer 102. The quantized prediction error is entropy-encoded by variable length encoder  
 103 and is stored in buffer 110. Buffer 110 outputs the stored occurring code (a bitstream)  
 with a certain timing. The quantized prediction error is returned to the original spatial domain  
 again as a local decoding process by dequantizer 104 and inverse frequency convertor 105.  
 Further, the predicted value is added to the prediction error returned to the spatial domain, and  
 10 the prediction error is stored in frame memory 106 as a reconstructed picture.

[0007]

The reconstructed picture that has been stored in frame memory 106 is referred by  
 intra-frame predictor 107, motion compensator 108 and motion estimator 109 to produce the  
 predicted value. Therefore, the reconstructed picture stored in frame memory is also called a  
 15 reference frame.

[0008]

The above is the principle operation in the moving picture compression technique.

[0009]

In general, in a digital broadcast system, service and the like, the moving picture signal  
 20 is controlled about the occurring code amount, i.e., the bit rate thereof for transmission/storage.  
 Code amount control unit 111 performs the two steps, as described later, in order to control the  
 bit rate.

[0010]

In the first step, code amount control unit 111 sets a target code amount for each frame  
 25 in accordance with each picture type. When R is a code amount assigned to a frame that have  
 not been encoded in GOP, Np and Nb are numbers of P-pictures and B-pictures, which have not  
 been encoded in GOP, respectively, Xi, Xp, Xb are parameters, each of which represents frame  
 complexity of each picture, defined by equations (1) to (3), and Kp and Kb are parameters in  
 consideration of subjective picture qualities by picture type, target code amounts Ti, Tp, Tb by  
 30 picture types are then given by equations (4) to (6).

[0011]

$$X_i = Q_i \times C_i \quad (1),$$

$$X_p = Q_p \times C_p \quad (2),$$

$$X_b = Q_b \times C_b \quad (3),$$

$$T_i = R / (1 + N_p \times X_p / (K_p \times X_i) + N_b \times X_b / (K_b \times X_i)) \quad (4),$$

$$T_p = R / (N_p + N_b \times K_p \times X_b / (K_b \times X_p)) \quad (5), \text{ and}$$

$$T_b = R / (N_b + N_p \times K_b \times X_p / (K_p \times X_b)) \quad (6).$$

Where  $C_i$ ,  $C_p$ ,  $C_b$  are occurring code amounts of I-, P-, B-pictures that are finally coded, and  $Q_i$ ,  $Q_p$ ,  $Q_b$  are average quantization step sizes of I-, P-, B-pictures that are finally coded.

[0012]

Whenever each frame is encoded in accordance with the first process and the second process, which will be described later, code amount  $R$  assigned to a frame that has not been encoded in GOP is updated by equation (7).

[0012]

$$R = R - C_{i,p,b} \quad (7).$$

Further, when a head picture of GOP is encoded, code amount  $R$  is initialized by equation (8).

$$R = \text{bit\_rate} \times N / \text{frame\_rate} + R \quad (8).$$

Where,  $\text{bit\_rate}$  is a target bit rate,  $\text{frame\_rate}$  is a frame rate, and  $N$  is the number of frames in GOP.

[0013]

In the second step, in order to coincide code amounts  $T_i$ ,  $T_p$ ,  $T_b$  assigned to respective frames, obtained in the first step, with actual occurring code amounts, quantization steps are obtained by feedback control in macroblock units in accordance with the virtual buffer capacity that is set by each picture type.

[0014]

First, prior to encoding of the  $j$ -th macroblock, occupation amounts in the virtual buffer are obtained by picture types in accordance with equation (9).

$$d_{i,p,b}(j) = d_{i,p,b}(0) + B(j-1) - T_{i,p,b} \times (j-1) / \text{MBcount} \quad (9).$$

$d_{i,p,b}(0)$  is an initial occupation amount in the vertical buffer,  $B(j)$  is an occurring code amount from a head to the  $j$ -th macroblock in the frame, and  $\text{MBcount}$  is the number of macroblocks in the frame.

30 [0015]

When encoding of each frame is finished, initial occupation amounts  $d_{i,p,b}(\text{MBcount})$  in the vertical buffer by picture types are used as initial occupation amounts  $d_{i,p,b}(0)$  in the vertical buffer relative to the next picture.

[0016]

Then, quantization step size  $Q(j)$  relative to the  $j$ -th macroblock is calculated in accordance with equation (10).

$$Q(j) = Q_{i,p,b} \times d_{i,p,b}(j) \times 31 / (10 \times r) \quad (10), \text{ and}$$

$$Q_{i,p,b} = X_{i,p,b} / T_{i,p,b} \quad (11).$$

Where  $r$  is a parameter used to control the response speed of the feedback loop, which is called a reaction parameter, and is represented by equation (12).

$$r = 2 \times \text{bit\_rate} / \text{frame\_rate} \quad (12).$$

Incidentally, initial occupation amounts  $d_{i,p,b}(0)$  in the virtual buffer at the start of encoding are represented by equations (13) to (15).

$$d_i(0) = 10 \times r / 31 \quad (13),$$

$$d_p(0) = K_p \times d_i(0) \quad (14), \text{ and}$$

$$d_b(0) = K_b \times d_i(0) \quad (15).$$

On the other hand, a moving picture encoding scheme is proposed in which a multi-frame motion prediction that enables the motion prediction is incorporated, that is, the P-picture is predicted from not only the I-picture or the P-picture that is just previously encoded but also the frame that is already encoded and the B-picture is predicted from not only the I-picture or the P-picture that is just previously encoded but also the B-picture that is already encoded. In this scheme, since a high-quality frame that is previously encoded is selected, and then the motion prediction can be performed degree of freedom in the motion prediction increases.

[Disclosure of Invention]

[Problems to be solved by the invention]

[0017]

However, the conventional moving picture encoding controls the code amount assigned to each frame only by using the picture type and the complexity of each picture that is finally encoded, without using the degree of freedom in the motion prediction according to the multi-frame motion prediction. Therefore, according to the conventional technique, in the moving picture compression using the multi-frame motion prediction, moving pictures are not encoded in a high picture quality by using the multi-frame motion prediction effectively. Such a technique is desired.

[0018]

The present invention is made by considering the above problem. An object of the present invention is to provide a moving picture encoding technique of encoding a moving picture in a high picture quality by effectively using the multi-frame prediction.

[Means for Solving the Problems]

[0019]

The first invention for solving the above problem is a moving picture encoding method for performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that:

the method includes, in reference frames used for the multi-frame motion prediction, a frame that has been encoded in a higher picture quality than the other frames of the same picture type.

[0020]

The second invention for solving the above problem is characterized in that, in the above first invention, the frame encoded in the higher picture quality is a frame to which more code amount is assigned than the other frames of the same picture type.

[0021]

The third invention for solving the above problem is characterized in that, in the above first or second invention, the frame encoded in the higher picture quality is a frame having a smaller quantizing parameter than the other frames of the same picture type.

[0022]

The fourth invention for solving the above problem is characterized in that, in any one of the above first to third inventions, the frame encoded in the higher picture quality is a P-picture frame.

[0023]

The fifth invention for solving the above problem is characterized in that, in any one of the above first to fourth inventions, the frame encoded in the higher picture quality is a B-picture frame.

[0024]

The sixth invention for solving the above problem is characterized in that, in the above fifth invention, in comparison with a final B-picture frame in the continuous B-picture frames, a B-picture frame prior to the final B-picture frame is encoded in the higher picture quality.

[0025]

The seventh invention for solving the above problem is characterized in that, in any one of the above first to sixth inventions, the frames encoded in the higher picture quality are arranged at constant frame intervals.

[0026]

The eighth invention for solving the above problem is characterized in that, in any one

of the above first to seventh inventions, a frame interval of the frames encoded in the higher picture quality is adaptively changed in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[0027]

5           The ninth invention for solving the above problem is a moving picture encoding apparatus for performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that the apparatus comprises:

encoding means for encoding at least one frame in a plurality of reference frames in a higher picture quality than the other frames of the same picture type.

10           [0028]

The tenth invention for solving the above problem is characterized in that, in the above ninth invention, the encoding means assigns more code amount to a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[0029]

15           The eleventh invention for solving the above problem is characterized in that, in the above ninth or tenth invention, the encoding means sets a smaller quantizing parameter for a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[0030]

20           The twelfth invention for solving the above problem is characterized in that, in any one of the above ninth to eleventh inventions, the encoding means encodes a P-picture frame in the higher picture quality.

[0031]

25           The thirteenth invention for solving the above problem is characterized in that, in any one of the above ninth to twelfth inventions, the encoding means encodes a B-picture frame in the higher picture quality.

[0032]

30           The fourteenth invention for solving the above problem is characterized in that, in the above thirteenth invention, in comparison with a final B-picture frame in the continuous B-picture frames, the encoding means encodes a B-picture frame prior to the final B-picture frame in the higher picture quality.

[0033]

The fifteenth invention for solving the above problem is characterized in that, in any one of the above ninth to fourteenth inventions, the encoding means arranges the frames

encoded in the higher picture quality at constant frame intervals.

[0034]

The sixteenth invention for solving the above problem is characterized in that, in any one of the above ninth to fifteenth inventions, the encoding means adaptively changes a frame  
5 interval of the frames encoded in the higher picture quality in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[0035]

The seventeenth invention for solving the above problem is a moving picture encoding  
10 program causing an information processing apparatus to execute encoding by performing a multi-frame motion prediction with reference to a plurality of picture frames, characterized in that:

the moving picture encoding program causing the information processing apparatus to execute a process of:

15 encoding at least one frame in a plurality of reference frames in a higher picture quality than the other frames of the same picture type.

[0036]

The eighteenth invention for solving the above problem is characterized in that, in the above seventeenth invention, the moving picture encoding program causes the information  
20 processing apparatus to execute a process of assigning more code amount to a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[0037]

The nineteenth invention for solving the above problem is characterized in that, in the  
25 above seventeenth or eighteenth inventions, the moving picture encoding program causes the information processing apparatus to execute a process of setting a smaller quantizing parameter for a frame than the other reference frames of the same picture type to encode the frame in the higher picture quality.

[0038]

30 The twentieth invention for solving the above problem is characterized in that, in any one of the above seventeenth to nineteenth inventions, the moving picture encoding program causes the information processing apparatus to execute a process of encoding a P-picture frame in the higher picture quality.

[0039]

The twenty-first invention for solving the above problem is characterized in that, in any one of the above seventeenth to twentieth inventions, the moving picture encoding program causes the information processing apparatus to execute a process of encoding a B-picture frame in the higher picture quality.

5 [0040]

The twenty-second invention for solving the above problem is characterized in that, in the above twenty-first invention, the moving picture encoding program causes the information processing apparatus to execute a process of, in comparison with a final B-picture frame in the continuous B-picture frames, encoding a B-picture frame prior to the final B-picture frame in  
10 the higher picture quality.

[0041]

The twenty-third invention for solving the above problem is characterized in that, in any one of the above seventeenth to twenty-second inventions, the moving picture encoding program causes the information processing apparatus to execute a process of arranging the  
15 frames encoded in the higher picture quality at constant frame intervals.

[0042]

The twenty-fourth invention for solving the above problem is characterized in that, in any one of the above seventeenth to twenty-third inventions, the moving picture encoding program causes the information processing apparatus to execute a process of adaptively  
20 changing a frame interval of the frames encoded in the higher picture quality in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

[0043]

The twenty-fifth invention for solving the above problem is a moving picture data  
25 input/output apparatus to/from which moving picture data encoded by performing a multi-frame motion prediction with reference to a plurality of picture frames is input or output, characterized in that:

the moving picture data which is input or output includes, in reference frames used for the multi-frame motion prediction, a frame encoded in a higher picture quality than the other  
30 frames of the same picture type.

[0044]

The twenty-sixth invention for solving the above problem is characterized in that, in the above twenty-fifth invention, the frame encoded in the higher picture quality in the motion picture data is a frame to which more code amount is assigned than the other frames of the same

picture type.

[0045]

5 The twenty-seventh invention for solving the above problem is characterized in that, in the above twenty-fifth or twenty-sixth invention, the frame encoded in the higher picture quality in the motion picture data is a frame having a smaller quantizing parameter than the other frames of the same picture type.

[0046]

10 The twenty-eighth invention for solving the above problem is characterized in that, in any one of the above twenty-fifth to twenty-seventh inventions, the frame encoded in the higher picture quality in the motion picture data is a P-picture frame.

[0047]

The twenty-ninth invention for solving the above problem is characterized in that, in any one of the above twenty-fifth to twenty-seventh inventions, the frame encoded in the higher picture quality in the motion picture data is a B-picture frame.

15 [0048]

The thirtieth invention for solving the above problem is characterized in that, in the above twenty-fifth invention, in comparison with a final B-picture frame in the continuous B-picture frames, a B-picture frame prior to the final B-picture frame is encoded in the higher picture quality.

20 [0049]

The thirty-first invention for solving the above problem is characterized in that, in any one of the above twenty-fifth to thirtieth inventions, in the motion picture data, the frames encoded in the higher picture quality are arranged at constant frame intervals.

[0050]

25 The thirty-second invention for solving the above problem is characterized in that, in any one of the above twenty-fifth to thirty-first inventions, in the motion picture data, a frame interval of the frames encoded in the higher picture quality is adaptively changed in accordance with differential information and motion information between a reference frame and a subject frame to be encoded.

30 [Advantageous Effect of the Invention]

[0051]

According to the present invention, in the moving picture compression using the multi-frame motion prediction, not the picture type and the complexity of each picture that is finally encoded are simply used, but code amount control is performed so as to improve the

effects of the motion prediction of the whole scene by encoding a frame having high priority as a reference frame in a high picture quality in consideration of the relationship between the subject frame to be encoded and the reference frame in the multi-frame motion prediction. Therefore, in the moving picture compression using the degree of freedom of the motion prediction by the multi-frame motion prediction, the present invention can provide the moving picture encoding method of the higher picture quality.

[0052]

Also, in accordance with the scene of the moving picture, frames to be encoded in a higher picture quality are arranged at constant frame intervals or the frame interval of frames to be encoded in a higher picture quality are adaptively changed in accordance with differential information and motion information between the reference frame and the subject frame to be encoded, thereby precisely selecting the reference frame to be encoded in a higher picture quality with priority, and thus the code amount control for moving pictures in the higher picture quality can be provided. Accordingly, the moving pictures can be encoded in a still higher picture quality.

[0053]

Also, the more code amount is assigned to the B-picture frame with high priority as a reference frame, thereby providing code amount control for moving pictures in a higher picture quality. Accordingly, since the effects of the motion prediction of the whole sequence can be improved, moving pictures can be encoded in a higher picture quality.

[Best Mode for Carrying Out the Invention]

[0054]

In the present invention, in the moving picture compression using the multi-frame motion prediction, not the picture type and the complexity of each picture that is finally encoded are simply used, but an encode amount is controlled in a manner that effects of motion prediction of whole scene are improved, in consideration of the relationship between a subject frame to be encoded and a reference frame in the multi-frame motion prediction, by encoding a frame with a high priority as the reference frame in a high picture quality.

[0055]

Incidentally, in the following description, "scene" means any number of continuous frames. "A frame is encoded in a high picture quality" means that more code amount is assigned to the frame, or that the quantization step size of the frame is made small, or that coding distortion in the frame is reduced.

[0056]

Hereinafter, the modes for carrying out the present invention are explained as compared with the conventional art.

[0057]

According to the present invention, in the moving picture encoding method using the multi-frame motion prediction, picture qualities of frames of the same picture type are not even but variable, thereby enhancing the effects of the motion prediction of the whole scene to provide an encoding technique of a moving picture in a high picture quality.

[0058]

As described above, in the conventional moving picture encoding method using the motion prediction method, because the motion prediction is performed only by the picture that has been just encoded, only the encoding can be performed in which the picture qualities of frames of the same picture type are kept even. As its reason, when the picture qualities in the same scene are varied, a difference between frames increases in a frame that refers to another frame in the lowered picture quality and the effects of the motion prediction are lowered. Therefore, the encoding efficiency of the whole scene is lowered, and thus the picture quality of the moving picture that is encoded is lowered.

[0059]

Next, this problem is explained with reference to Fig. 2.

[0060]

In the conventional motion prediction shown in Fig. 2, each P-picture refers to only the I- or P-picture that has been just encoded. Even if P<sub>2</sub>, P<sub>4</sub> frames are tried to be encoded in a higher quality than P<sub>1</sub>, P<sub>3</sub> frames, P<sub>1</sub> frame is encoded in the low picture quality, and therefore the effects of the motion prediction in P<sub>2</sub> frame that refers to P<sub>1</sub> frame are significantly lowered and the picture quality in P<sub>2</sub> frame is also significantly lowered. The picture quality in P<sub>3</sub> frame that refers to P<sub>2</sub> frame is also significantly lowered, and because the picture quality lowering propagates in the following frames, the picture quality of the whole scene is lowered. Therefore, in the method using the conventional motion prediction, the picture quality of pictures of the same picture type must be kept even.

[0061]

However, like the coding method to which the present invention is applied, there is a multi-frame motion prediction that can perform a motion prediction, by referring to not only the frame that has been just encoded, but also the frames that have been already encoded. In the case of Fig. 2, according to the multi-frame motion prediction, predictions of dot lines can be performed in addition to the conventional method (i.e., a frame to be referred can be selected by

an area or by a block in the frame).

[0062]

With this multi-frame prediction arrangement, it is possible to perform the encoding that varies the picture quality in spite of the same picture type. The present invention is explained with reference to Fig. 2.

[0063]

In the multi-frame motion prediction of Fig. 2, each P-picture refers to a plurality of I- or P-pictures that have been just encoded. In this example, two I- or P-pictures are referred. Even if  $P_1$  frame is encoded in the low quality when  $P_2$ ,  $P_4$  frames are tried to be encoded in a higher quality than  $P_1$ ,  $P_3$  frames, in  $P_2$  frame that refers to not only  $P_1$  frame but also  $I_0$  frame, the effects of the motion prediction are not significantly lowered. Therefore,  $P_2$  frame is encoded in a higher quality.

[0064]

Also, the effects of the motion prediction in  $P_3$  frame that refers to  $P_2$  frame encoded in the high picture quality are enhanced, and  $P_3$  frame is encoded in a higher quality than the conventional art. Further, since  $P_4$  frame refers to  $P_2$ ,  $P_3$  frames that are encoded in the high picture quality,  $P_4$  frame is encoded in a higher quality. In the following frames, the effects of the motion prediction are enhanced and moving pictures can be encoded in a high picture quality, similarly to the above frames.

[0065]

With this arrangement, the effects of the motion prediction are enhanced rather than the conventional art, and moving pictures can be encoded in a high picture quality. Also, the moving pictures that are encoded according to the present invention subjectively provide the higher picture quality than the conventional art, because the frames that are encoded in the high picture quality are periodically displayed when being decoded, and by persistence of vision, i.e., by the human visual feature.

[0066]

In the above description, the example using only I- and P-picture is shown, however, the present invention is available to a case of using I-, P-, and B-pictures are used.

[0067]

With reference to Fig. 3, the problem of the conventional art and the solutions by the present invention will be explained. Incidentally, explanations are given below while paying attention to only B-picture because the basic concept relative to P-picture is similar to that shown in Fig. 2.

[0068]

In the conventional art, the B-picture frame is a frame not to be referred, i.e., a frame that is not referred from another frame, and the effects of the motion prediction in respective B-pictures, which are continuous, are equal. Therefore, the same code amount is assigned to the respective B-frames, which are continuous, and the B-frames are encoded in the same picture quality. As the reason in that the effects of the motion prediction of respective B-pictures, which are continuous, are made equal, when attention is given to B<sub>1</sub> and B<sub>2</sub> frames in the example of Fig. 3, distances from I<sub>0</sub>, P<sub>3</sub> frames to B<sub>1</sub> frame are respectively one and two, and distances from I<sub>0</sub>, P<sub>3</sub> frames to B<sub>2</sub> frame are respectively two and one, and both totals of frame distances for determining the effects of the motion prediction are three.

[0069]

However, in the moving picture encoding that uses the multi-frame motion prediction, a B-picture can also refer to another B-picture that is previously encoded. Therefore, the effects of the motion prediction of continuous B-pictures are variable. When an attention is given to B<sub>1</sub> and B<sub>2</sub> frames in Fig. 3, B<sub>2</sub> frame can perform the motion prediction that refers to not only I<sub>0</sub> frame but also B<sub>1</sub> frame having a short inter-frame distance, and B<sub>2</sub> frame can provide higher performance of the motion prediction than B<sub>1</sub> frame, as is apparent. Therefore, even if the same code amount is not assigned to B<sub>1</sub> and B<sub>2</sub> frames, B<sub>1</sub> and B<sub>2</sub> frames can be encoded in the same picture quality.

[0070]

With this technique, in the moving picture encoding method using the multi-frame motion prediction, the present invention provides a moving picture encoding method in a high picture quality by distributing a code amount to a leading reference B-frame by priority in order of encoding in continuous B-frames. Thus, regarding B<sub>1</sub> and B<sub>2</sub> frames in FIG. 3, as the code amount is assigned to B<sub>1</sub> frame by priority, B<sub>1</sub> frame is encoded in the higher picture quality than the conventional art. B<sub>2</sub> frame, which refers to B<sub>1</sub> frame encoded in the higher picture quality, can be encoded in a higher picture quality. In other words, by varying picture qualities of B-picture frames, the effects of the whole motion prediction are enhanced and moving pictures can be encoded in a higher picture quality.

[0071]

Explanations are given below of concrete Examples of the present invention.

[Example 1]

[0072]

Fig. 4 is a block diagram of the present invention in Example 1. The present

invention further includes picture quality control unit 112 in addition to the conventional art. The operation of code amount control unit 111 in the present invention is different from the conventional art based on picture quality control information supplied from picture quality control unit 112.

5 [0073]

In Example 1, the operation is explained when I-picture and P-picture are used as picture types used to encode frames.

[0074]

10 Incidentally, in the following description, explanations are given of picture quality control unit 112 and code amount control unit 111, which are difference between Example 1 and the conventional art shown in Fig. 1.

[0075]

Picture quality control unit 112 includes picture quality determination unit 1121 and picture quality control counter 1122.

15 [0076]

Fig. 5 is a block diagram of picture quality control unit 112.

[0077]

20 The picture quality control information supplied from picture quality control unit 112 includes high picture quality flag HQ\_flg, number of remaining high picture quality frames R\_HQ\_num, and remaining high picture quality frame number R\_HQ\_frame\_num.

[0078]

25 Picture quality determination unit 1121 in picture quality control unit 112 calculates high picture quality flag HQ\_flg, number of high picture quality frames R\_HQ\_num, and high picture quality frame number R\_HQ\_frame\_num. The high picture quality flag is supplied to code amount control unit 111. The number of high picture quality frames and the high picture quality frame number are supplied to picture quality control counter 1122.

[0079]

30 The operation of picture quality determination unit 1121 according to Example 1 is explained with reference to Fig. 6. Fig. 6 is a flowchart illustrating the operation of picture quality determination unit 1121 in the present embodiment.

[0080]

In the following explanation, an interval of frames to be encoded in a high picture quality is represented by S, a frame number that has been just determined to be encoded in a high picture quality is represented by prev\_fnum (initial value = 0), and the number of frames

that have been determined to be in a high picture quality is represented by  $i$  (initial value = 0). Additionally, frame interval  $S$  is not more than  $MAX\_REF$  which is an interval between a subject frame to be encoded and the previous-most frame that can be referred by the multi-frame prediction. The operation in each step will be explained.

5 [0081]

Incidentally, frame interval  $S$  that is encoded in a high picture quality may be changed in accordance with a motion speed or a frame rate after compression by a certain period (by GOP or by a scene). By selecting frame interval  $S$  by GOP or by scene so as to be suitable thereto, the encoding efficacy according to the present invention is further improved.

10 [0082]

In step S101, picture quality determination unit 1121 calculates number of high picture quality frames  $HQ\_num$  by using equation (16) based on frame interval  $S$  and number  $N$  of frames in GOP.

$$HQ\_num = (N/S) - 1 \quad (16).$$

15 In step S102, picture quality determination unit 1121 determines whether or not number  $i$  of frames that have been determined to be in a high picture quality is smaller than number of high picture quality frames  $HQ\_num$ . When smaller, step S103 is executed, and when not smaller, the process is finished.

[0083]

20 In step S103, picture quality determination unit 1121 calculates high picture quality frame number  $HQ\_frame\_num[i]$  by using equation (17). Further, number  $i$  of frames that have been determined to be in a high picture quality is incremented by 1, frame number  $prev\_fnum$  that has been just determined to be encoded in a high picture quality is updated by equation (18), and step S102 is executed.

25  $HQ\_frame\_num[i] = prev\_hq\_num + S \quad (17), \text{ and}$   
 $prev\_fnum = HQ\_frame\_num[i] \quad (18).$

After the above processes, picture quality determination unit 1121 turns  $HQ\_flag$  on when  $HQ\_num$  is not less than 1 and turns  $HQ\_flag$  off when less than 1.

[0084]

30 According to the process shown in Fig. 6, the reference frame to be referred is encoded in a high picture quality at interval  $S$ . Because  $S$  is not more than interval  $MAX\_REF$  of previous-most frame that can be referred in the multi-frame prediction, the motion prediction can be necessarily performed in all subject frames to be encoded while referring to frames that are encoded in the high picture quality.

[0085]

As an example, Fig. 7 shows frames to be encoded in the high picture quality according to the proposed method in the case of  $N=10$ ,  $MAX\_REF=3$ , and  $S=2$ .

[0086]

5           Picture quality control counter 1122 calculates number of remaining high picture quality frames  $R\_HQ\_num$  and remaining high picture quality frame number  $R\_HQ\_frame\_num$  in accordance with frame number coding\_frame\_num supplied from code amount control unit 111 and number of high picture quality frames  $HQ\_num$  and high quality frame number  $HQ\_frame\_num[HQ\_num]$  supplied from picture quality determination unit  
10   1122, and outputs them to code amount control unit 111.

[0087]

          Picture quality control counter 1122 operates only when number of high picture quality frames  $HQ\_num$  is not less than 1. Here, the frame number of I-picture at the head of GOP is represented by  $frame\_num\_I$ , high picture quality frame counter  $HQ\_frame\_count$  is set to 0,  
15   and the operation of picture quality control counter 1122 in the present embodiment is explained with reference to Fig. 8. Fig. 8 is a flowchart corresponding to the operation of picture quality control counter 1122 in Example 1.

[0088]

          In step S201, picture quality control counter 1122 adds  $frame\_num\_I$  to high picture  
20   quality frame number  $HQ\_frame\_num[HQ\_frame\_count]$  supplied from picture quality determination unit 1121. This operation is performed to synchronize frame number coding\_frame\_num in being encoded, supplied from code amount control unit 111, with the frame number to be encoded in a high picture quality.

[0089]

25           In step S202, picture quality control counter 1122 takes  $HQ\_frame\_num[HQ\_frame\_count]$  as remaining high picture quality frame number  $R\_HQ\_frame\_num$  and outputs  $(HQ\_num - HQ\_frame\_count)$  as number of remaining high picture quality frames  $R\_HQ\_num$ .

[0090]

30           In step S203, picture quality control counter 1122 determines whether or not frame number coding\_frame\_num is synchronized with high picture quality frame number  $HQ\_frame\_num[HQ\_frame\_count]$ . When they are synchronized, step S204 is executed, and when they are not synchronized, step S202 is executed.

[0091]

In step S 204, picture quality control counter 1122 increments HQ\_frame\_count by 1. When HQ\_frame\_count is smaller than HQ\_num, the process is returned to step S201, and when not smaller, the process is finished.

[0092]

5           Code amount control unit 111, as shown in Fig. 9, frame code amount assignment unit 1111 and quantizing parameter update unit 1112. The difference between Example 1 and the conventional art in code amount control unit 111 is only in the operation of frame code amount assignment unit 1111.

[0093]

10           Frame code amount assignment unit 1111 calculates an assigned code amount for each frame by using the picture quality control information supplied from picture quality control unit 112 and supplies the assigned code amounts to quantizing parameter update unit 1112.

[0094]

15           Quantizing parameter update unit 1112 calculates a quantizing parameter by using the frame assignment code amount supplied from frame code amount assignment unit 1111 and the occurring code amount supplied from buffer 110.

[0095]

20           Frame code amount assignment unit 1111 performs frame code amount assignment using high picture quality flag HQ\_flg, number of remaining high picture quality frames R\_HQ\_num, and remaining high picture quality frame number R\_HQ\_frame\_num in the picture quality control information supplied from picture quality control unit 112.

[0096]

The operation of frame code amount assignment unit 1111 is explained below.

[0097]

25           In the following explanations, it is assumed that target code amounts  $T_i$ ,  $T_p$  are target code amounts by picture type,  $R$  is a code amount assigned to frames that have not been encoded in GOP,  $N_p$  is the number of P-pictures that have not been encoded in GOP,  $X_i$  is screen complexity of I-picture that is finally encoded,  $X_p$  is screen complexity of P-picture that is finally encoded, and  $K_p$  is a parameter by picture type in consideration of the subjective  
30 picture quality.

[0098]

Fig. 10 is a flowchart showing the operation of frame code assignment unit 1111 in Example 1.

[0099]

In step S301, frame code amount assignment unit 1111 determines whether the high picture quality flag supplied from picture quality control unit 112 is turned on or off. When the high picture quality flag is turned on, step S302 is executed, and when off, step S307 is executed.

5 [0100]

In step S302, it is determined whether or not the frame to be being encoded is I-picture. When the subject frame to be encoded is I-picture, step S303 is executed, and when not I-picture, step S304 is executed.

[0101]

10 In step S303, frame code amount assignment unit 1111 calculates code amount  $T_i$  for I-picture that is being coded, by equation (19) and finishes the frame code amount assignment.

$$T_i = R/(1 + N_p \times X_p/X_i) + \text{additional\_}T_i \quad (19),$$

$$\text{additional\_}T_i = \text{residu1\_bit1} \times X_i/X_{\text{gop2}} \quad (20),$$

$$\text{residu\_bit1} = (\text{margin\_ratio} \times R \times (N_p - R\_HQ\_num) \times X_p)/(K_p \times X_{\text{gop1}}) \quad (21),$$

15  $X_{\text{gop1}} = X_i + N_p \times X_p/K_p \quad (22), \text{ and}$

$$X_{\text{gop2}} = X_i + R\_HQ\_num \times X_p/K_p \quad (23).$$

Where, margin\_ratio is a number not more than 1.

[0102]

20 Since the number of bits more then the conventional art by additional\_ $T_i$  is assigned to this frame, the picture quality of this frame is improved. Accordingly, the effects of the frame motion prediction that refers to this frame are improved.

[0103]

25 In step S304, frame code amount assignment unit 1111 determines whether or not frame number coding\_frame\_num of P-picture that is being encoded is synchronized with remaining high picture quality frame number R\_HQ\_frame\_num supplied from picture quality control unit 112. When they are synchronized, step S305 is executed, and when not synchronized, step S306 is executed.

[0104]

30 In step S305, frame code amount assignment unit 1111 calculates the code amount for P-picture that is being encoded by equation (24) and finishes the frame code amount assignment.

$$T_p = R/N_p + \text{additional\_}T_p \quad (24), \text{ and}$$

$$\text{additional\_}T_p = (\text{margin\_ratio} \times R \times (N_p - R\_HQ\_num))/(N_p \times R\_HQ\_num) \quad (25).$$

Since the number of bits more than the conventional art by additional  $T_p$  is assigned to this frame, the picture quality of this frame is improved. Accordingly, the effects of the frame motion prediction that refers to this frame are also improved.

[0105]

5 In step S306, frame code amount assignment unit 1111 calculates the code amount for P-picture that is being encoded by equation (26) and finishes the frame code amount assignment.

$$T_p = (1 - \text{margin\_ratio}) \times R/N_p \quad (26).$$

10 Since the code amount assigned to the frame is decreased by  $\text{margin\_ratio}$ , it is considered that the picture quality of this frame is lowered. However, since the motion prediction can be performed by control of picture quality control unit 112 while referring to the frames encoded in the high picture quality, the picture quality can be prevented from lowering by improvement of motion prediction performance, even if the assigned code amount is small.

[0106]

15 In step S307, frame code amount assignment unit 1111 determines whether or not the frame that is being encoded is I-picture. When the subject frame to be encoded is I-picture, step S308 is executed, and when not I-picture, step S309 is executed.

[0107]

20 In step S308, frame code amount assignment unit 1111 calculates the code amount for I-picture that is being encoded by equation (27) and finishes the frame code amount assignment.

$$T_i = R/(1 + N_p \times X_p/X_i) \quad (27).$$

25 In step S309, frame code amount assignment unit 1111 calculates the code amount for P-picture that is being encoded by equation (28) and finishes the frame code amount assignment.

$$T_p = R/N_p \quad (28).$$

30 According to the code amount assignment, as described above, all frames can refer to the frames encoded in the high picture quality by using the degree of freedom of the motion prediction in the multi-frame motion prediction. With this arrangement, since the effects of the motion prediction of the whole scene are improved, moving pictures can be encoded in a high picture quality.

[0108]

Quantizing parameter update unit 1112 performs feedback control to a quantizing parameter by macroblock, based on the virtual buffer capacity that is set for each picture type,

in order to match code amounts  $T_{i,p}$  that are assigned to respective frames and are obtained in frame code amount assignment unit 1111 with the actual occurring code amounts. Figure 11 is a flowchart of updating the quantizing parameter.

[0109]

5 In step S401, quantizing parameter update unit 1112 calculates an occupation amount of the virtual buffer by picture type with equation (29) prior to encoding of the  $j$ -th macroblock.

$$d_{i,p}(j) = d_{i,p}(0) + B(j-1) - T_{i,p} \times (j-1) / \text{MBcount} \quad (29).$$

Where  $d_{i,p}(0)$  is an initial occupation amount in the virtual buffer,  $B(j)$  is an occurring code amount from the head of the frame to the  $j$ -th macroblock, and MBcount is the number of  
10 macroblocks in the frame.

[0110]

At the completion of encoding each frame, initial occupation amounts  $d_{i,p}(\text{MBcount})$  in the virtual buffer by picture type are used as initial occupation amounts  $d_{i,p}(0)$  in the virtual buffer for the next picture.

15 [0111]

In step S402, quantizing parameter update unit 1112 calculates the quantization step size relative to the  $j$ -th macroblock by equation (30).

$$Q_{\text{step}} = Q_{i,p} \times d_{i,p}(j) \times 31 / (10 \times r) \quad (30), \text{ and}$$

$$Q_{i,p} = X_{i,p} / T_{i,p} \quad (31).$$

20 With control by frame code amount assignment unit 1111, assignment code amounts  $T_{i,p}$  of frames to be encoded in the high picture quality become larger than those of the conventional art. Therefore, due to the calculation of equation (31), quantization step sizes  $Q_{i,p}$  of high picture quality frames are small and the frames are encoded in the high picture quality. Accordingly, the average quantizing parameter of the frames of the bitstream to be  
25 output provides small values at frame intervals of  $S$ .

[0112]

Here,  $r$  is a parameter, called a reaction parameter, for controlling the response speed of the feedback loop, and is given by equation (32).

$$r = 2 \times \text{bit\_rate} / \text{frame\_rate} \quad (32).$$

30 Incidentally, at start of encoding, initial occupation amounts  $d_{i,p}(0)$  of the virtual buffer are given by equations (33), (34).

$$d_i(0) = 10 \times r / 31 \quad (33), \text{ and}$$

$$d_p(0) = K_p \times d_i(0) \quad (34).$$

In step S 403, quantizing parameter update unit 1112 detects quantizing parameter  $Q$

corresponding to quantization step size  $Q_{step}$  from a quantization table. When there is no quantization step size  $Q_{step}$  in the quantization table, quantizing parameter  $Q$  of the quantization step size closest to quantization step size  $Q_{step}$  is output.

[0113]

5           The explanation of Example 1 is completed here.

[Example 2]

[0114]

Example 2 of the present invention is explained.

[0115]

10          Fig. 12 is a block diagram of the present invention in Example 2.

[0116]

It is the characteristic matter of Example 2 that it further includes moving picture analysis unit 113 in addition to the arrangement of Example 1. The operation of picture quality control unit 112 in Example 2 is different from the conventional art due to frame differential information and frame motion information both supplied from moving picture analysis unit 113.

[0117]

Incidentally, in Example 2, the operation of the invention is explained for a case where I-picture and P-picture are used as picture types to encode frames.

20          [0118]

In addition, in the following description, explanations are given of moving picture analysis unit 112 and picture quality control unit 112, which are difference between Example 2 and Example 1.

[0119]

25          Moving picture analysis unit 113 includes input frame buffer 1131 and motion detection unit 1132. Fig. 13 is a block diagram of moving picture analysis unit 113.

[0120]

Moving picture analysis unit 113 calculates the frame differential information and the frame motion information from the input picture, and supplies the calculated information to picture quality control unit 112.

30          [0121]

Each input frame buffer 1131 and motion detection unit 1132, which constitute moving picture analysis unit 113, will be explained below.

[0122]

Input frame buffer 1131 foresees N-pieces of input moving picture frames, allocates numbers to respective frames in ascending order, and stores the frames in a buffer. The number of frames to be foreseen is arbitrary, and, for example, it can be considered that the GOP interval used in MPEG is used as N.

5 [0123]

Motion detection unit 1132 calculates the frame motion information and frame differential information of each frame in accordance with the frames stored in input frame buffer 1131.

[0124]

10 The operation of motion detection unit 1132 is explained with reference to Fig. 14. Fig. 14 is a flowchart showing the operation of motion detection unit 1132 in the present embodiment. Motion detection unit 1132 performs steps described below for each frame, which is foreseen.

[0125]

15 In step S501, motion detection unit 1132 divides the frame into blocks of  $w \times h$  in size smaller than the frame size of  $W \times H$ .

[0126]

20 In step S 502, motion detection unit 1132 calculates block motion information MVX, MVY and block differential information D of the blocks to form the frame in accordance with the following process.

[0127]

A pixel value at coordinate (x, y) in the cur-th frame is set as  $F(\text{cur}, x, y)$ , the k-th divided block in the cur-th frame is set as  $B(\text{cur}, k)$ , and a coordinate at the upper-left corner of  $B(\text{cur}, k)$  in the frame is set as  $(\text{bx}(\text{cur}, k), \text{by}(\text{cur}, k))$ .

25 [0128]

Block motion information  $MVX(\text{cur}, k, \text{ref})$ ,  $MVY(\text{cur}, k, \text{ref})$  and differential information  $D(\text{cur}, k, \text{ref})$  of block (cur, k) in the cur-th frame, relative to a previous frame by ref-pieces, i.e., (cur - ref)-th frame, are given by mvx, mvy that minimize  $\text{diff}(\text{ref}, \text{mvx}, \text{mvy})$  in equation (35) and minimized  $\text{diff}(\text{ref}, MVX(\text{cur}, k, \text{ref}), MVY(\text{cur}, k, \text{ref}))$ .

30

$$\text{diff}(\text{ref}, \text{mvx}, \text{mvy}) = \sum_{i=0}^{l=w-1} \sum_{j=0}^{j=h-1} \text{abs}(\text{cur\_pixel}(i, j) - \text{ref\_pixel}(\text{ref}, i + \text{mvx}, j + \text{mvy})) \quad (35),$$

$$\text{cur\_pixel}(i, j) = F(\text{cur}, \text{bx}(\text{cur}, k) + i, \text{by}(\text{cur}, k) + j) \quad (36), \text{ and}$$

$$\text{ref\_pixel}(\text{ref}, i, j) = F(\text{cur} - \text{ref}, \text{bx}(\text{cur}, k) + i, \text{by}(\text{cur}, k + j)) \quad (37).$$

In step S503, motion detection unit 1132 calculates the frame motion information and the frame differential information from block motion information MVX, MVY and block differential information D.

[0129]

5 When the number of blocks in the frame is set as block\_num, frame motion information FMVj(i) and frame differential information FDj(i) of the i-th frame relative to the (i-j)-th frame are given by equations (38) and (39).

$$FMVj(i) = \sum_{n=0}^{block\_num-1} (abs(MVX(i, n, j) + MVY(i, n, j))) \quad (38),$$

$$FDj(i) = \sum_{n=0}^{block\_num-1} D(i, n, j) \quad (39).$$

10 Motion detection unit 1132 performs the above-mentioned process for each frame i ( $1 \leq i \leq N-1$ ) and each reference frame ref ( $1 \leq ref \leq MAX\_REF$ ) and calculates the frame differential information and the frame motion information between all the input frames and the reference frames.

[0130]

15 Picture quality control unit 112 includes picture quality determination unit 1121 and picture quality control counter 1122. Fig. 15 is a block diagram of picture quality control unit 112.

[0131]

20 Picture quality control information supplied from picture quality control unit 112 includes a high picture quality flag, the number of remaining high picture quality frames, and a remaining high picture quality frame number.

[0132]

The difference of picture quality control unit 112 of Example 2 from picture quality control unit 112 Example 1 is only in the operation of picture quality determination unit 1121.

25 [0133]

Therefore, only the operation of picture quality determination unit 1121 according to the present embodiment is explained below.

[0134]

30 Picture quality determination unit 1121 calculates the high picture quality flag, the number of high picture quality frames, and the high picture quality frame number in accordance with the frame differential information and the frame motion information supplied from moving picture analysis 112. The high picture quality flag is output to code amount control unit 111,

and the number of high picture quality frames and the high picture quality frame number are output to picture quality control counter 1122.

[0135]

The operation of picture quality determination unit 1121 according to the present embodiment is explained below with reference to Fig. 16. Fig. 16 is a flowchart showing the operation of picture quality determination unit 1121 in Example 2.

[0136]

In step S601, picture quality determination unit 1121 calculates inter-frame cost IFC(i) of each frame i and reference frame j by using equation (40).  $\alpha$  is a value depending on the average quantizing parameter of the frame.

$$IFC_j(i) = FD_j(i) + \alpha \times FMV_j(i) \quad (40).$$

In step S602, picture quality determination unit 1121 calculates minimum inter-frame cost MIN\_IFC(i) ( $1 \leq i \leq N-1$ ) by using equation (41) and obtains best reference frame BEST\_REF(i) corresponding to MIN\_IFC(i). Here, MAX\_REF is an interval between the subject frame to be encoded and the previous-most frame that can be referred in the multi-frame prediction.

$$MIN\_IFC(i) = \min_{\arg 1 \leq j \leq MAX\_REF} \{IFC_j(i)\} \quad (41).$$

In step S603, picture quality determination unit 1121 determines whether or not BEST\_REF(i) ( $1 \leq i \leq N-1$ ) of all frames are 1. As shown in Fig. 17, when BEST\_REF(i) of all frames are 1, a continuous scene is predicted without momentary picture fluctuations, such as a scene change and a flash, in N-pieces of analysis sections. Therefore, when all BEST\_REF(i) are 1, the process is advanced to step S604, and when all BEST\_REF(i) are not 1, the high picture quality flag is turned off and the number of high picture quality frames is set to 0, and then the process is finished.

[0137]

In step S604, picture quality control unit 112 calculates average inter-frame cost AVERAGE\_IFC, inter-frame cost upper limit IFC\_UPPER\_LIMIT, and inter-frame cost lower limit IFC\_LOWER\_LIMIT in accordance with MIN\_IFC(i) ( $=IFC_1(i)$ ) of all frames by equations (42) to (44). Here, margin\_ratio is a value not more than 1.

$$AVERAGE\_IFC = \sum_{i=1}^{N-1} MIN\_IFC(i) / (N-1) \quad (42),$$

$$IFC\_UPPER\_LIMIT = (1 + margin\_ratio) \times AVERAGE\_IFC \quad (43), \text{ and}$$

$$IFC\_LOWER\_LIMIT = (1 - margin\_ratio) \times AVERAGE\_IFC \quad (44).$$

In step S605, picture quality control unit 112 analyzes whether or not MIN\_IFC(i) ( $1 \leq i \leq N-1$ ) of all frames are within a range between IFC\_LOWER\_LIMIT and IFC\_UPPER\_LIMIT.

[0138]

5 When MIN\_IFC(i) of all N-1 pieces of picture frames are within the above-mentioned range, as shown in Fig. 18, the difficulty of the inter-frame prediction is stable, and when not within the range, the difficulty is unstable.

[0139]

10 Therefore, picture quality control unit 112 turns the high picture quality flag on and advances the process to step S606 when MIN\_IFC(i) of all frames are within the above-mentioned range in step S605. Otherwise, picture quality control unit 112 turns the high picture quality flag off, sets the number of high picture quality frames to 0, and terminates the following process.

[0140]

15 In step S606, picture quality control unit 112 adaptively calculates frame interval S to be encoded in a high picture quality within SS in accordance with the process, which will be described later, while maximum high picture quality frame interval set by GOP or scene is represented by SS and is a value not more than the interval between the subject frame to be encoded and the previous-most frame that can be referred in the multi-frame prediction.

20 [0141]

In this description, maximum high picture quality frame interval SS is suitably set in accordance with the motion speed and the frame rate after moving picture compression.

[0142]

25 The number of continuous frames not over IFC\_UPPER\_LIMIT is represented by s\_frame (initial value = 1), frame number that has been just determined to be encoded in a high picture quality is represented by prev\_fnum (initial value = 0), and frame number in picture quality determination process is represented by i (initial value = 2), and an example of the calculation method for the number of high picture quality frames HQ\_num (initial value = 0) and high picture quality frame number HQ\_frame\_num[N-1] is shown with reference to Fig.

30 19.

[0143]

Fig. 19 is a flowchart showing inside of step S606 in the picture quality determination according to the present embodiment.

[0144]

In step S701, picture quality control unit 112 determines whether or not  $IFCs\_frame+1(i)$  is larger than  $IFC\_UPPER\_LIMIT$ , executes step S702 when  $IFCs\_frame+1(i)$  is larger than  $IFC\_UPPER\_LIMIT$ , and executes step S707 when not larger.

[0145]

5 In step S702, picture quality control unit 112 obtains the high picture quality frame number in accordance with equation (45), updates  $prev\_fnum$ ,  $HQ\_num$ , and  $s\_frame$  in accordance with equations (46) to (48), and executes step S706.

$$HQ\_frame\_num[hq\_num] = prev\_fnum + s\_frame \quad (45),$$

$$prev\_fnum = HQ\_frame\_num[hq\_num] \quad (46),$$

10  $HQ\_fnum = HQ\_fnum + 1 \quad (47), \text{ and}$

$$s\_frame = 1 \quad (48).$$

In step S703, picture quality control unit 112 determines whether or not  $s\_frame$  is equal to  $SS-1$ , executes step S704 when equal, and executes step S705 when not equal.

[0146]

15 In step S704, picture quality control unit 112 obtains the high picture quality frame number in accordance with equation (45) while setting  $s\_frame=SS$ , updates  $prev\_fnum$ ,  $HQ\_num$ , and  $s\_frame$  in accordance with equations (46) to (48), and increments frame number  $i$  by 1. Then, step S706 is executed.

[0147]

20 In step S705, picture quality control unit 112 increments  $s\_frame$  by 1, and executes step S706.

[0148]

In step S706, picture quality control unit 112 increments frame number  $i$  to be processed by 1, determines whether or not  $i$  is smaller than number  $N$  of foreseeing frames, and  
25 returns to step S701 when small and finishes the process when not small.

[0149]

With the above-mentioned process, while all the subject frames to be encoded refer to the frames that are coded in the high picture quality without exception, the motion prediction becomes possible.

30 [0150]

Fig. 20 shows an example in that the above-mentioned high picture quality encoding frame determination is executed when  $N=15$ ,  $REF\_NUM=3$ , and the leading frame, that is, 0-th frame, is I-picture. According to the inventive method, frame interval  $S$  to be coded in the high picture quality is updated adaptively.

[0151]

Incidentally, when HQ\_num obtained by the above-mentioned picture quality determination process is equal to N-1, namely, when it is determined that all frames are encoded in the high picture quality, HQ\_num is reset to 0, the high picture quality flag is turned  
5 off, and the number of high picture quality frames is set to 0.

[0152]

By arranging moving picture analysis unit 113 is arranged, it is possible to select the frame to be encoded in the high picture quality with accuracy, in consideration of momentary picture fluctuations, such as a scene change and a flash, in GOP, i.e., rapid reduction of pixel  
10 correlation between continuous frames and the effects of large fluctuations in encoding difficulty of the scene. Accordingly, moving pictures can be encoded a still higher picture quality.

[0153]

The example of Example 2 has been explained above. The present invention is not  
15 limited to the above examples. The present invention can be achieved by a simple embodiment using inter-frame cost IFC(i). For example, when the interval between the subject frame to be encoded and the previous-most frame that can be referred in the multi-frame prediction is MAX\_REF, high picture quality frame number R\_HQ\_frame\_num that has been just encoded in the high picture quality is regarded as one of reference frames and, in frame  
20 number (R\_HQ\_frame\_num + m) where  $m \leq \text{MAX\_REF}$ , a frame of which inter-frame cost IFC(i) relative to the high picture quality reference frame is smaller than a predetermined threshold and which corresponds to maximum m can be set as the next high picture quality frame.

[0154]

The explanation of Example 2 is completed here.

[Example 3]

[0155]

Example 3 of the present invention is explained. In Example 3, the operation of the invention in case that I-picture, P-picture, and B-picture are used as picture types used to  
30 encode frames will be explained.

[0156]

The arrangement in Example 3 is similar to the arrangement in Example 1. However, Example 3 is different from Example 1 in the operations of picture quality control unit 112 and code amount control unit 111, because encoding is performed by using B-picture.

[0157]

Hereinafter, explanations are given of the operations of picture quality control unit 112 and code amount control unit 111.

[0158]

5           Picture quality control unit 112 includes picture quality determination unit 1121 and picture quality control counter 1122, similarly to Example 1.

[0159]

10           In the high picture quality flag, the number of remaining high picture quality frames, and the high picture quality frame number of the picture quality control information which is supplied to code amount control unit 111 from picture quality control unit 112, the number of remaining high picture quality frames and the high picture quality frame number relate to P-picture frames in Example 1, whereas they relate to B-picture frames in Example 3.

[0160]

15           Accordingly, Example 3 is different from Example 1 only in the operation of picture quality determination unit 1121 in picture quality control unit 112. Therefore, only the operation of picture quality determination unit 1121 in Example 3 will be explained below.

[0161]

20           Fig. 21 is a flowchart illustrating the operation of picture quality determination unit 1121 in the Example. The calculation procedure for number of high picture quality frames HQ\_num (initial value = 0) and high picture quality frame number HQ\_frame\_num[HQ\_num] is explained with reference to Fig. 21, when the number of frames included in GOP is set to N and the frame number in picture quality determination process is set to i (initial value = 1).

[0162]

25           In step S801, picture quality determination unit 1121 determines whether or not the coding type of the i-th frame that is currently to be analyzed is B-picture. When the coding type is B-picture, step S802 is executed, and when not B-picture, step S804 is executed.

[0163]

30           In step S802, picture quality determination unit 1121 determines whether or not the coding type of the successive (i+1)-th frame is B-picture. When the coding type is B-picture, step S803 is executed, and when not B-picture, step S804 is executed.

[0164]

          In step S803, picture quality determination unit 1121 stores the current i-th frame as a frame to be encoded in a high picture quality in accordance with equation (49) and updates the number of high picture quality frames in accordance with equation (50).

HQ\_frame\_num[HQ\_num] = i (49), and

HQ\_num = HQ\_num + 1 (50).

In step S804, picture quality determination unit 1121 increments the frame number i to be processed by 1 and determines whether or not frame number i is smaller than N. When  
 5 frame number i is smaller than N, the process is returned to step S801, and when not smaller, the process is finished.

[0165]

After completion of the above processes, picture quality determination unit 1121 turns high picture quality flag HQ\_flg on when HQ\_num is not less than 1, and turns HQ\_flg off  
 10 when HQ\_num is less than 1.

[0166]

With the above process, the frame that is to be referred and is encoded as B-picture is regarded as a high picture quality frame number. In other words, the reference frame can be encoded in the high picture quality.

15 [0167]

Fig. 22 shows an example of B-picture encoded in the high picture quality according to such a process.

[0168]

Code amount control unit 111 includes frame code amount assignment unit 1111 and  
 20 quantizing parameter update unit 1112, similarly to Example 1. Explanations are given below of the operations of frame code amount assignment unit 1111 and quantizing parameter update unit 1112 in code amount control unit 111.

[0169]

Frame code amount assignment unit 1111 performs frame code amount assignment by  
 25 using the picture quality control information supplied from picture quality control unit 112, i.e., the high picture quality flag, number of remaining high picture quality frames R\_HQ\_num, and remaining high picture quality frame number R\_HQ\_frame\_num.

[0170]

Target code amounts Ti, Tp, Tb are regarded as target code amounts for respective  
 30 picture types, R is regarded as a code amount assigned to frames that have not been encoded in GOP, Np and Nb are regarded as numbers of P-pictures and B-pictures that have not been encoded in GOP, Xi, Xp, Xb are regarded as screen complexity of each picture that is finally encoded, and Kp and Kb are parameters in consideration of subjective picture quality by picture type. The operation of frame code amount assignment unit 1111 in the present Example is

explained with reference to Fig. 23.

[0171]

In step S901, frame code amount assignment unit 1111 determines whether high picture quality flag HQ\_flg supplied from picture quality control unit 112 is turned on or off.

5 When high picture quality flag HQ\_flg is turned on, step S 902 is executed, and when off, step S908 is executed.

[0172]

In step S902, frame code amount assignment unit 1111 determines the frame type of the frame, which is being encoded. In a case of I-picture, step S903 is executed, in a case of  
10 P-picture, step S904 is executed, and in the other case, i.e., in the case of B-picture, step S905 is executed.

[0173]

In step S903, frame code amount assignment unit 1111 calculates the code amount for I-picture, which is being encoded, in accordance with equation (51), and finishes the frame  
15 code amount assignment.

$$Ti = R / (1 + Np \times Xp / (Kp \times Xi) + Nb \times Xb / (Kb \times Xi)) + \text{additional\_Ti} \quad (51),$$

$$\text{additional\_Ti} = \text{residu\_bit3} \times Xi / Xgop4 \quad (52),$$

$$\text{residu\_bit3} = (\text{margin\_ratio} \times R \times (Nb - R\_HQ\_num) \times Xb) / (Kb \times Xgop3) \quad (53),$$

$$Xgop3 = Xi + Np \times Xp / Kp + Nb \times Xb / Kb \quad (54),$$

20 and

$$Xgop4 = Xi + Np \times Xp / Kp + (Nb - R\_HQ\_num) \times Xb / Kb \quad (55).$$

Since the more bits are assigned to this frame by additional\_Ti, in comparison with the conventional art, the picture quality of this frame is improved. Accordingly, the effects of the frame motion prediction that refers to this frame are improved.

25 [0174]

In step S904, frame code amount assignment unit 1111 calculates a code amount for P-picture, which is being encoded, in accordance with equation (56), and finishes the frame code amount assignment.

$$Tp = R / (Np + Nb \times Kp \times Xb / (Kb \times Xp)) + \text{additional\_Tp} \quad (56),$$

$$30 \quad \text{additional\_Tp} = \text{residu\_bit4} \times Xp / (Kp \times Xgop6) \quad (57),$$

$$\text{residu\_bit4} = (\text{margin\_ratio} \times R \times (Nb - R\_HQ\_num) \times Xb) / (Kb \times Xgop5) \quad (58),$$

$$Xgop5 = Np \times Xp / Kp + Nb \times Xb / Kb \quad (59), \text{ and}$$

$$Xgop6 = Np \times Xp / Kp + (Nb - R\_HQ\_num) \times Xb / Kb \quad (60).$$

Since the more bits are assigned to this frame by additional\_Tp, in comparison with the

conventional art, the picture quality of this frame is improved. Accordingly, the effects of the frame motion prediction that refers to this frame are improved.

[0175]

In step S905, frame code amount assignment unit 1111 determines whether or not  
5 frame number coding\_frame\_num of B-picture, which is being encoded, is synchronous with remaining high picture quality frame number R\_HQ\_frame\_num supplied from picture quality control unit 112. When they are synchronous, step S906 is executed, and when not synchronous, step S907 is executed.

[0176]

10 In step S906, frame code amount assignment unit 1111 calculates a code amount for B-picture, which is immediately coded, in accordance with equation (61), and finishes the frame code amount assignment.

$$Tb = R/(Nb + Np \times Kb \times Xp/(Kp \times Xb)) + \text{additional\_Tb} \quad (61), \text{ and}$$

$$\text{additional\_Tb} = \text{residu\_bit4} \times Xb/(Kb \times Xgop6) \quad (62).$$

15 Since the more bits are assigned to this additional\_Tb in comparison with the conventional art, the picture quality of this frame is improved. Accordingly, the effects of the frame motion prediction that refers to this frame are improved.

[0177]

In step S907, frame code amount assignment unit 1111 calculates a code amount for  
20 B-picture, which is immediately coded, in accordance with equation (63), and finishes the frame code amount assignment.

$$Tb = (1 - \text{margin\_ratio}) \times R/(Nb + Np \times Kb \times Xp/(Kp \times Xb)) \quad (63).$$

25 Since the code amount assigned to this is reduced by margin\_ratio, lowering in the picture quality of this frame is considered. However, with control of picture quality control unit 112, the motion prediction can be performed while I-, P-, B-frames that are encoded in the high picture quality are referred. Accordingly, even if the code amount is small to some degree, lowering in the picture quality is prevented by improvement of the motion prediction performance.

[0178]

30 In step S908, frame code amount assignment unit 1111 determines the picture type of the frame, which is being encoded. In a case of I-picture, step S909 is executed, in a case of P-picture, step S910 is executed, and in the other case, i.e., in the case of B-picture, step S911 is executed.

[0179]

In step S909, frame code amount assignment unit 1111 calculates the code amount for I-picture, which is being encoded, in accordance with equation (64), and finishes the frame code amount assignment.

$$T_i = R / (1 + N_p \times X_p / (K_p \times X_i) + N_b \times X_b / (K_p \times X_i)) \quad (64).$$

5 In step S910, frame code amount assignment unit 1111 calculates the code amount for P-picture, which is being encoded, in accordance with equation (65), and finishes the frame code amount assignment.

$$T_p = R / (N_p + N_b \times K_p \times X_b / (K_b \times X_p)) \quad (65).$$

10 In step S911, frame code amount assignment unit 1111 calculates the code amount for B-picture, which is being encoded, in accordance with equation (66), and finishes the frame code amount assignment.

$$T_b = R / (N_b + N_p \times K_b \times X_p / (K_p \times X_b)) \quad (66).$$

15 With the above code amount assignment, without assigning a residual code amount to B-picture frames having low priority as reference frames, frames that are referred and are encoded as I-, P-, B-pictures can be encoded in the high picture quality. Accordingly, the motion prediction can be performed for all frames by the frames that are encoded in the high picture quality, and moving pictures can be encoded in the high picture quality.

[0180]

20 Quantizing parameter update unit 1112 obtains a quantizing parameter according to feedback control by macroblock, based on the virtual buffer capacity that is set for each picture type, in order to match code amounts  $T_{i,p,b}$  that are obtained in frame code amount assignment unit 1111 and are assigned to respective frames with the actual occurring code amounts.

[0181]

25 The operation of quantizing parameter update unit 1112 is similar to that of Example 1, the operation of each step is explained with reference to the flowchart in Fig. 11, in order to correspond to a variable name for each picture types.

[0182]

30 In step S401, quantizing parameter update unit 1112 calculates an occupation amount of the virtual buffer by each picture type with equation (67) prior to encoding of the j-th macroblock.

$$d_{i,p,b}(j) = d_{i,p,b}(0) + B(j-1) - T_{i,p,b} \times (j-1) / MBcount \quad (67).$$

Where,  $d_{i,p,b}(0)$  is an initial occupation amount in the virtual buffer,  $B(j)$  is an occurring code amount from the head of the frame to the j-th macroblock, and MBcount is the number of macroblocks in the frame.

[0183]

At completion of encoding of each frame, the initial occupation amount in the virtual buffer for each frame  $di_{p,b}(MBcount)$  is used as an initial occupation amount  $di_{p,b}(0)$  in the virtual buffer for the next picture.

5 [0184]

In step S402, quantizing parameter update unit 1112 calculates the quantization step size relative to the  $j$ -th macroblock by equation (68).

$$Qstep = Qi_{p,b} \times di_{p,b}(j) \times 31 / (10 \times r) \quad (68), \text{ and}$$

$$Qi_{p,b} = Xi_{p,b} / Ti_{p,b} \quad (69).$$

10 With control by frame code amount assignment unit 1111, assignment code amounts  $Ti_{p,b}$  of frames to be encoded in a high picture quality become larger than those of the conventional art, and code amount  $Tb$  of B-picture that is roughly encoded becomes smaller than that of the conventional art.

[0185]

15 According to equation (69), quantization step size  $Qb$  of B-picture frames that is encoded in the high picture quality becomes small, and quantization step size  $Qb$  of B-picture frames that is roughly encoded becomes large. In other words, the B-picture frame having high priority as a reference frame to be referred is encoded in a higher picture quality than the B-picture frame having low priority as the reference frame to be referred.

20 [0186]

Here,  $r$  is a parameter used to control the response rate of the feedback loop, which is called a reaction parameter, and is represented by equation (70).

$$r = 2 \times \text{bit\_rate} / \text{frame\_rate} \quad (70).$$

25 Incidentally, initial values  $di_{p,b}(0)$  in the virtual buffer at start of encoding are represented by equations (71) to (73).

$$di(0) = 10 \times r / 31 \quad (71),$$

$$dp(0) = Kp \times di(0) \quad (72), \text{ and}$$

$$db(0) = Kb \times di(0) \quad (73).$$

30 In step S 403, quantizing parameter update unit 1112 detects quantizing parameter  $Q$  corresponding to quantization step size  $Qstep$  from a quantization table. When there is no corresponding quantization step size  $Qstep$  in the quantization table, quantizing parameter update unit 1112 outputs quantization parameter  $Q$  of the quantization step size value closest to quantization step size  $Qstep$ .

[0187]

The explanation of Example 3 is completed here.

[Example 4]

[0188]

Example 4 of the present invention is explained. In Example 4, the operation of the invention in case that I-picture, P-picture, and B-picture are used as picture types used to encode frames will be explained.

[0189]

The arrangement in Example 4 is similar to the arrangement in Example 4. However, Example 4 is different from Example 3 in the operations of picture quality control unit 112 and code amount control unit 111, because encoding is performed by using B-picture.

[0190]

Code amount control unit 111 in this Example is the same as code amount control unit 111 in Example 3. Therefore, only the operation of picture quality control unit 112 in this Example is explained below.

15 [0191]

Picture quality control unit 112 includes picture quality determination unit 1121 and picture quality control counter 1122, similarly to Example 3.

[0192]

The difference of Example 4 from Example 3 is that the operation of picture quality determination circuit 1121 by the frame differential information and the frame motion information supplied from moving picture analysis unit 112 is changed. Therefore, only the operation of picture quality determination unit 1121 in Example 4 will be explained below.

[0193]

Fig. 24 is a flowchart showing the operation of picture quality determination unit 1121 according to the present embodiment.

[0194]

The calculation procedure for number of high picture quality frames HQ\_num (initial value = 1) and high picture quality frame number HQ\_frame\_num[HQ\_num] is explained with reference to Fig. 24, when the number of frames included in GOP is set to N and the frame number in picture quality determination process is set to i (initial value = 0).

[0195]

In step S1001, picture quality determination unit 1121 firstly calculates inter-frame cost  $IFC1(i)$  of each frame  $i$  and the reference frame thereof by using frame differential information  $FD1(i)$  and frame motion information  $FMV1(i)$  supplied from moving picture

analysis unit 113 in accordance with equation (40).

[0196]

Secondly, picture quality determination unit 1121 obtains IFC\_UPPER\_LIMIT and IFC\_LOWER\_LIMIT in accordance with equations (42) to (44) on the assumption of  
5 MIN\_IFC(i)=IFC(i) in equation (42).

[0197]

Thirdly, picture quality determination unit 1121 determines whether or not all of IFC1(i) satisfy  $IFC\_LOWER\_LIMIT < IFC(i) < IFC\_UPPER\_LIMIT$ . When all of IFC1(i) are within the above range, the process is advanced to step S1002 while setting  $i=1$ , and when not,  
10 the process is finished.

[0198]

In step S1002, picture quality determination unit 1121 determines whether or not the coding type of the  $i$ -th frame that is currently to be analyzed is B-picture. When the coding type is B-picture, step S1003 is executed, and when not B-picture, step S1005 is executed.

15 [0199]

In step S1003, picture quality determination unit 1121 determines whether or not the coding type of the successive  $(i+1)$ -th frame is B-picture. When the coding type is B-picture, step S1004 is executed, and when not B-picture, step S1005 is executed.

[0200]

20 In step S1004, picture quality determination unit 1121 stores the current  $i$ -th frame as high picture quality frame number HQ\_frame\_num[HQ\_num] in accordance with equation (49) and updates number of high picture quality frames HQ\_num in accordance with equation (50).

[0201]

25 In step S1005, picture quality determination unit 1121 increments the frame number  $i$  to be processed by 1 and determines whether or not frame number  $i$  is smaller than number  $N$  of frames. When frame number  $i$  is smaller than  $N$ , the process is returned to step S1002, and when not smaller, the process is finished.

[0202]

30 After completion of the above processes, picture quality determination unit 1121 turns high picture quality flag HQ\_flg on when HQ\_num is not less than 1, and turns HQ\_flg off when HQ\_num is less than 1.

[0203]

Since moving picture analysis unit 113 is arranged, B-picture frames to be encoded in the high picture quality can be selected with accuracy, in consideration of momentary picture

fluctuations, such as a scene change and a flash, in GOP and the effects of large fluctuations in encoding difficulty of the scene. Accordingly, moving pictures can be encoded a still higher picture quality.

[Example 5]

5 [0204]

Example 5 of the present invention is explained. Example 5 is an information processing apparatus in which the moving picture encoding apparatus of the present invention is implemented. Fig. 25 is a block diagram of a typical configuration of the information processing system in which the moving picture encoding apparatus according to the present  
10 invention is implemented.

[0205]

The moving picture encoding apparatus according to the present invention can be configured by hardware, as is clear from the above explanations, and can be also carried out by a computer program.

15 [0206]

This information processing system shown in FIG. 25 includes processor 210, program memory 202, and storage media 203, 204. Storage media 203, 204 are separate storage media and different storage areas in one storage medium. As a storage medium, a magnetic storage medium such as a hard disk drive may be used.

20 [Example 6]

[0207]

Example 6 of the present invention is explained. Example 6 is an input/output apparatus to/from which the moving picture data (moving picture bitstream), for example, encoded by the moving picture encoding apparatus according to Examples 1 to 6 described  
25 above is input and output.

[0208]

In Example 6, as an example of the input/output apparatus to/from which the moving picture data (moving picture bitstream) is input and output, explanations are given of a receiver. However, there is no limitation on the input/output apparatus, and the input/output apparatus  
30 may be a frame synchronizer to/from which the moving picture data is input and output, a record apparatus such as a video apparatus, and the like.

[0209]

Incidentally, in Example 6, explanations are given of a receiver characterized by receiving, as inputs, moving picture encoded bit streams generated by Examples 1 and 2.

[0210]

As shown in Fig. 26, the arrangement of the receiver includes reference frame picture quality monitor 116 in addition to video decoder 115. The processing in video decoder 115 is identical to that in the conventional art.

5 [0211]

As shown in Fig. 26, the video decoder (decoder) includes dequantizer 104, inverse frequency convertor 105, frame memory 106, inter-frame predictor 107, motion compensator 108, and buffer 110, which constitute a local decoder in the encoder described in the section of Background Art. Further, video recorder 115 includes variable length decoder 114.

10 [0212]

Functions of these elements are similar to those of the encoder described above except the variable length decoder.

[0213]

The video bitstream mainly includes, as constituent elements, a conversion coefficient  
15 obtained by dividing an original input picture into a plurality of blocks with the encoder and by frequency converting and quantizing a prediction error signal, which a predicted value is subtracted by the inter-frame predictor or the motion compensator, and a code string, which a moving vector for generating the predicted value and the reference frame are variable length decoded.

20 [0214]

Variable length decoder 114 decodes the variable length code supplied from buffer 110, which is stored with the received bitstream, into original values. The decoded values include the conversion coefficient, the quantization parameter, the picture type, the motion vector, the reference frame, and the like.

25 [0215]

Dequantizer 104 dequantizes the conversion coefficient by using the quantizing parameter and generates a dequantization conversion coefficient.

[0216]

Inverse frequency converter 105 applies inverse frequency conversion to the  
30 dequantization conversion coefficient and generates a prediction error signal.

[0217]

The predicted value supplied from inter-frame prediction unit 107 or motion compensation unit 108 is added to the prediction error signal, and a decoded picture is obtained.

[0218]

The video decoder repeats these processes, thereby obtaining the decoded picture.

[0219]

The decoded picture is stored in frame memory 106 as a reconstructed picture and is used to generate the predicted value by inter-frame predictor 107, motion compensator 108, and  
5 motion estimator 109.

Next, the operation of reference frame picture quality monitor 114 is explained.

[0220]

Reference frame picture quality monitor 114 monitors the picture type, the reference frame, the quantizing parameter, the variable length code, and the frame memory supplied from  
10 video decoder 115, and outputs reference frame picture quality fluctuation information. The reference frame picture quality fluctuation flag indicates that the more code amount is assigned to the reference frame used for the motion compensation (multi-frame motion prediction) for decoding of the moving picture bitstream than other frames of the same picture type or whether or not a moving picture coding bitstream includes a frame having a small quantizing parameter.

[0221]

The reference frame picture quality fluctuation flag is specifically obtained by storing the picture type, the code amount, and the average quantizing parameter in decoding of the frame that is a reference frame to be referred after decoding and by checking that the more code amount is assigned to the reference frame stored in the memory frame than other frames of the  
20 same picture type or is obtained by checking whether or not a moving picture coding bitstream includes a frame having a small quantizing parameter.

[0222]

Figure 27 shows a flowchart for generating the reference frame picture quality fluctuation flag, where the picture type corresponding to reference frame number  $i$   
25 ( $1 < i < \text{MAX\_REF}$ ) stored in the frame memory is  $\text{pic\_type}(i)$ , the code amount of the whole frame is  $\text{total\_bit}(i)$ , and the average quantizing parameter of the whole frame is  $\text{average\_q}(i)$ . The process in each step is explained below.

[0223]

First, in step SA01, reference frame picture quality monitor 114 determines whether  
30 the picture type of the frame, which is being decoded, is P-picture or B-picture. When the picture type is P-picture or B-picture, the process is advanced to step SA02, and when neither P-picture nor B-picture, the reference frame picture quality fluctuation flag is turned off and the process is finished.

[0224]

In step SA02, reference frame picture quality monitor 114 determines that the more code amount is assigned to the i-th frame than the j-th reference frame (Condition 1:  $\text{total\_bit}(i) \approx (1 + \text{margin\_ratio}) \times \text{total\_bit}(j)$ ,  $\text{pic\_type}(i) = \text{pic\_type}(j)$ , and  $i \neq j$ ), or that the quantizing parameter is small (Condition 2:  $\text{average\_q}(i) \approx (1/(1 + \text{margin\_ratio})) \times \text{average\_q}(j)$ ,  $\text{pic\_type}(i) = \text{pic\_type}(j)$ , and  $i \neq j$ ), in a plurality of reference frames ref ( $1 < \text{ref} < \text{MAX\_REF}$ ) of the same picture type as the frame, which is being decoded. When Condition 1 or Condition 2 is satisfied, since the more code amount is assigned to the reference frame used by the moving picture bitstream for the motion prediction, than the other frames of the same picture type, or since such a reference frame is the moving picture encoded bitstream, reference frame picture quality monitor 114 turns the reference frame picture quality fluctuation flag on. When neither Condition 1 nor Condition 2 is satisfied, the reference frame picture quality fluctuation flag is turned off.

[0225]

Then, in step SA03, reference frame picture quality monitor 114 inspects the code length of the variable length code supplied from buffer 110 to calculate code amount tmp\_total\_bit of the whole subject frame to be decoded and calculates average quantizing parameter tmp\_avaerage\_Q of the whole frame from the quantizing parameter by MB supplied from variable length decoding 114. Also, at this time, picture type tmp\_pc\_type supplied from variable length decoding 114 is stored. With timing in that the current subject frame to be decoded is stored in frame memory 106 as number k after completion of decoding, reference frame picture quality monitor 114 stores tmp\_total\_bit, tmp\_avaerage\_Q, and tmp\_pc\_type into pic\_type(k), total\_bit(k), and average\_q(k), respectively, and then the process is finished.

[0226]

Incidentally, the above calculation of the reference frame picture quality fluctuation flag, like this, is performed whenever each frame is decoded.

[0227]

With the above processes, when the reference frame picture quality fluctuation flag is turned on, it can be confirmed that the more code amount is assigned to the moving picture bitstream generated by the encoding method of the present invention, which is the reference frame used for multi-frame motion prediction, than the other frames of the same picture type, or that the frame having the small quantizing parameter is included.

[Brief Description of the Drawings]

[0228]

[Fig. 1] Fig. 1 is a view showing a configuration of a conventional art.

[0229]

[Fig. 2] Fig. 2 is a view for explaining the present invention.

[0230]

[Fig. 3] Fig. 3 is a view for explaining the present invention.

5 [0231]

[Fig. 4] Fig. 4 is a diagram showing a configuration of Example 1.

[0232]

[Fig. 5] Fig. 5 is a block diagram of a picture quality control unit.

[0233]

10 [Fig. 6] Fig. 6 is a flowchart showing picture quality determination.

[0234]

[Fig. 7] Fig. 7 is a view for explaining a frame to be encoded in a high picture quality.

[0235]

15 [Fig. 8] Fig. 8 is a flowchart of a picture quality control counter.

[0236]

[Fig. 9] Fig. 9 is a block diagram of a code amount control unit.

[0237]

[Fig. 10] Fig. 10 is a flowchart of assigning a code amount to a frame.

20 [0238]

[Fig. 11] Fig. 11 is a flowchart of updating a quantizing parameter.

[0239]

[Fig. 12] Fig. 12 is a diagram showing a configuration of Example 2.

[0240]

25 [Fig. 13] Fig. 13 is a block diagram of a moving picture analysis unit.

[0241]

[Fig. 14] Fig. 14 is a flowchart of motion detection.

[0242]

[Fig. 15] Fig. 15 is a block diagram of a picture quality control unit.

30 [0243]

[Fig. 16] Fig. 16 is a flowchart of picture quality determination.

[0244]

[Fig. 17] Fig. 17 is a view for explaining an optimal reference frame.

[0245]

[Fig. 18] Fig. 18 is a view for explaining the difficulty of the inter-frame prediction.

[0246]

[Fig. 19] Fig. 19 is a flowchart of determination of a frame encoded in a high picture quality.

5 [0247]

[Fig. 20] Fig. 20 is a view for explaining a frame to be encoded in a high picture quality.

[0248]

[Fig. 21] Fig. 21 is a flowchart of picture quality determination.

10 [0249]

[Fig. 22] Fig. 22 is a view for explaining a frame to be encoded in a high picture quality.

[0250]

[Fig. 23] Fig. 23 is a flowchart of assigning a code amount to a frame.

15 [0251]

[Fig. 24] Fig. 24 is a flowchart of picture quality determination.

[0252]

[Fig. 25] Fig. 25 is a typical block diagram of an information processing system installed with the moving picture encoding apparatus according to the present invention.

20 [0253]

[Fig. 26] Fig. 26 is a diagram showing an example of a receiver to which a moving picture bitstream generated according to the present invention is supplied.

[0254]

[Fig. 27] Fig. 27 is a flowchart showing a process for generating a reference frame picture quality fluctuation flag.

[Explanation of Reference Numerals]

[0255]

101 Frequency conversion unit;

102 Quantization unit;

30 103 Variable length encoding unit;

104 Dequantization unit;

105 Inverse frequency conversion unit;

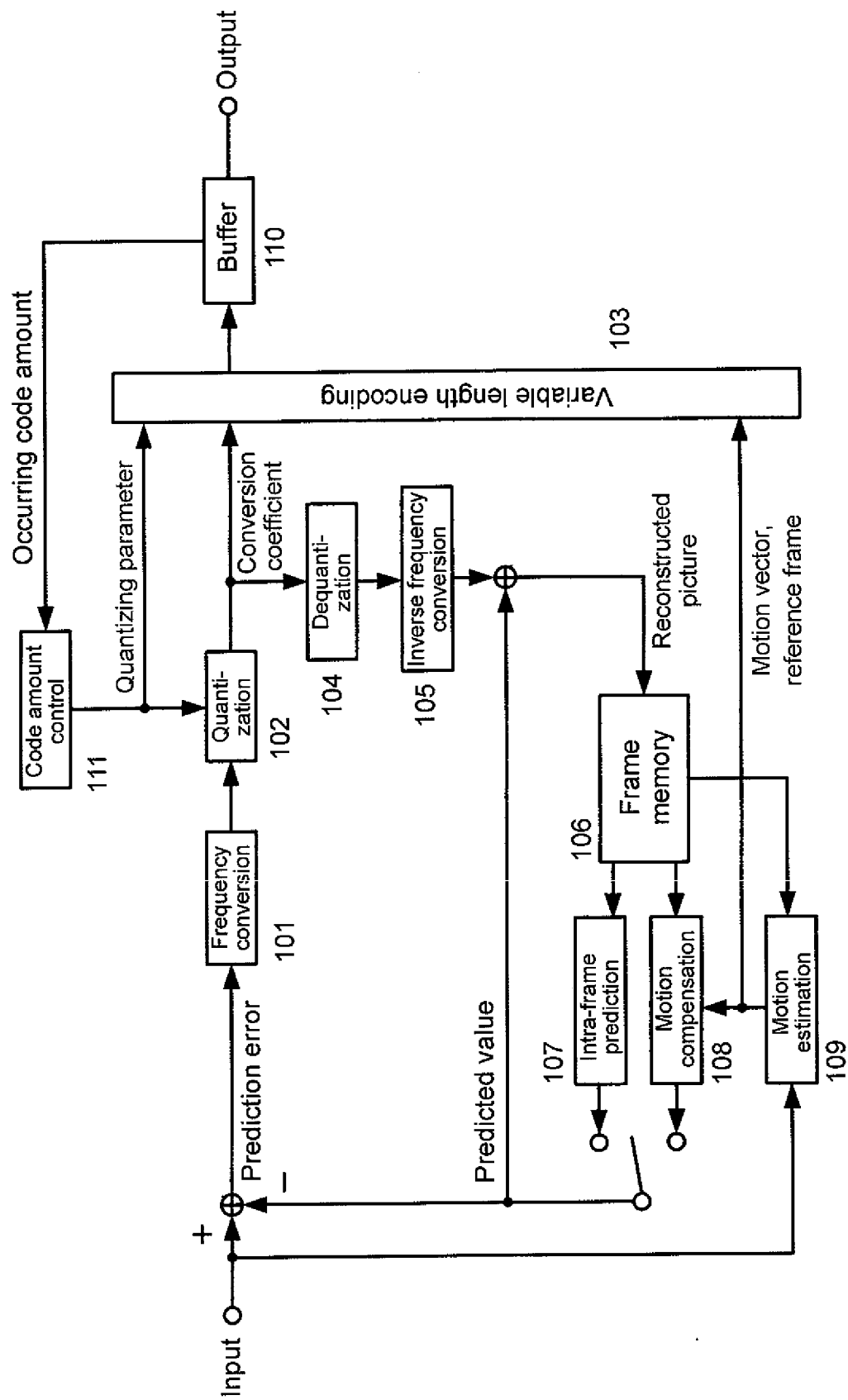
106 Frame memory;

107 Intra-frame prediction unit;

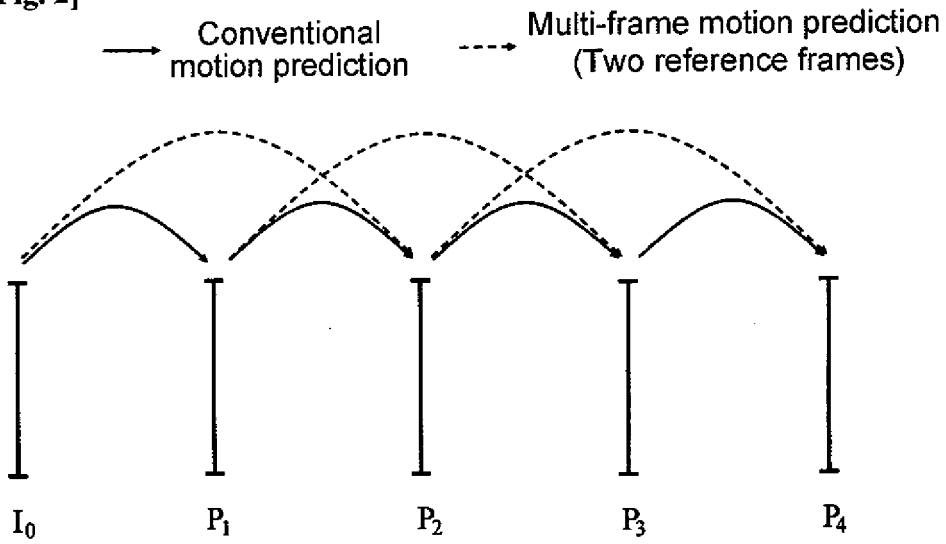
- 108 Motion compensation unit;
- 109 Motion estimation unit;
- 110 Buffer;
- 111 Code amount control unit;
- 5 1111 Frame code amount assignment unit;
- 1112 Quantizing parameter update unit;
- 112 Picture quality control unit;
- 1121 Picture quality determination unit;
- 1122 Picture quality control counter;
- 10 113 Moving picture analysis unit;
- 1131 Input frame buffer;
- 1132 Motion detection unit;
- 201 Processor;
- 202 Program memory;
- 15 203 Storage medium;
- 204 Storage medium.

[Document Name] DRAWINGS

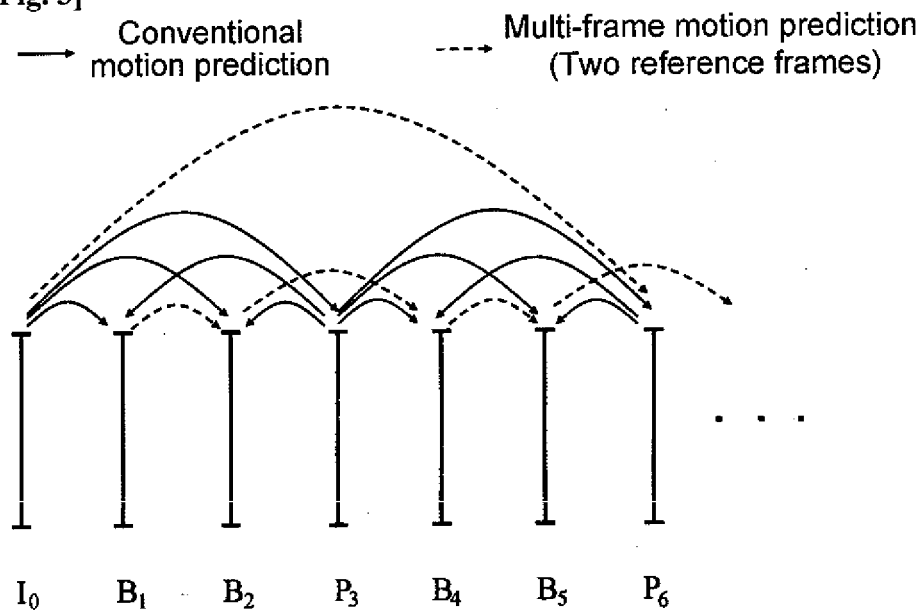
[Fig. 1]



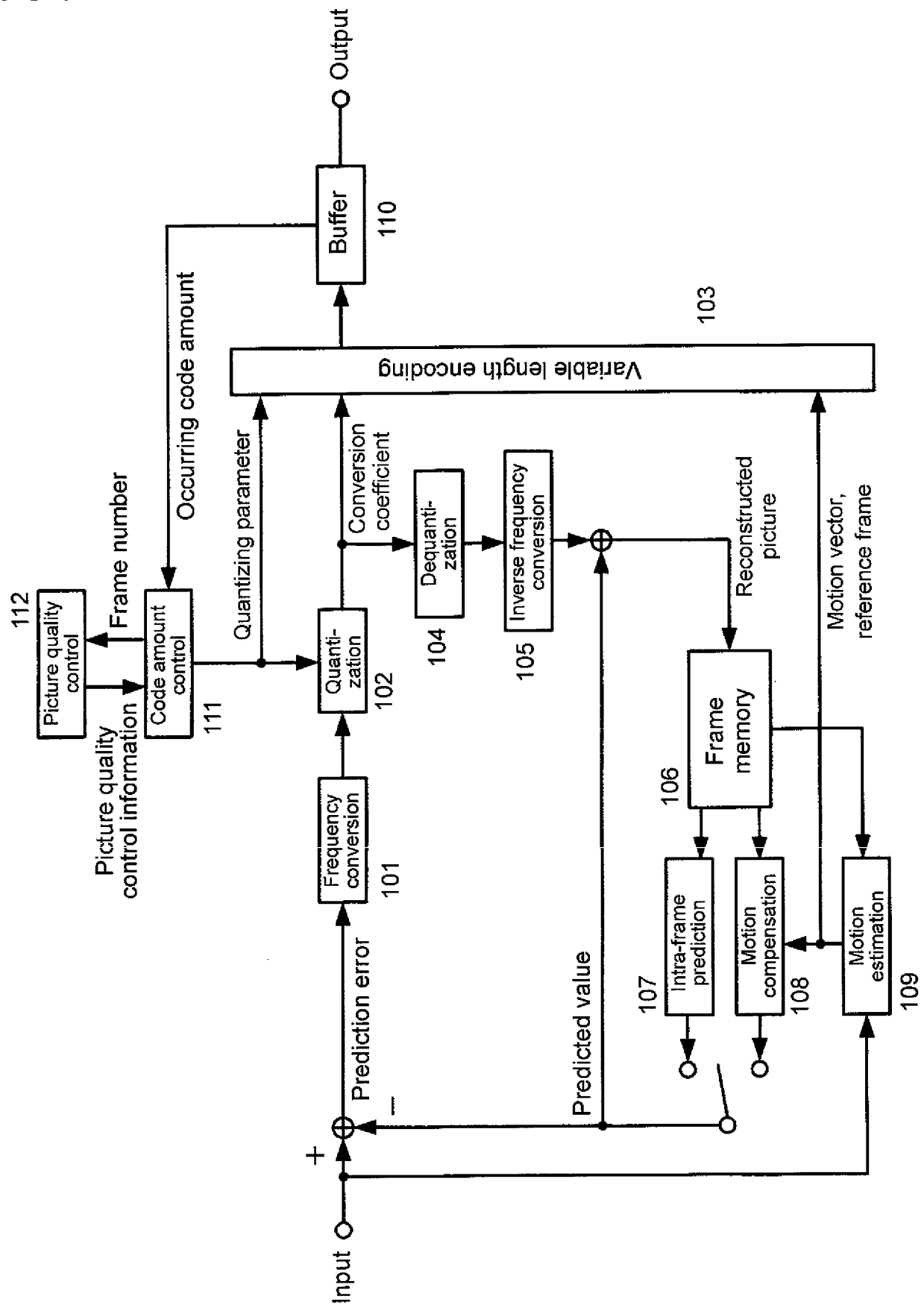
[Fig. 2]



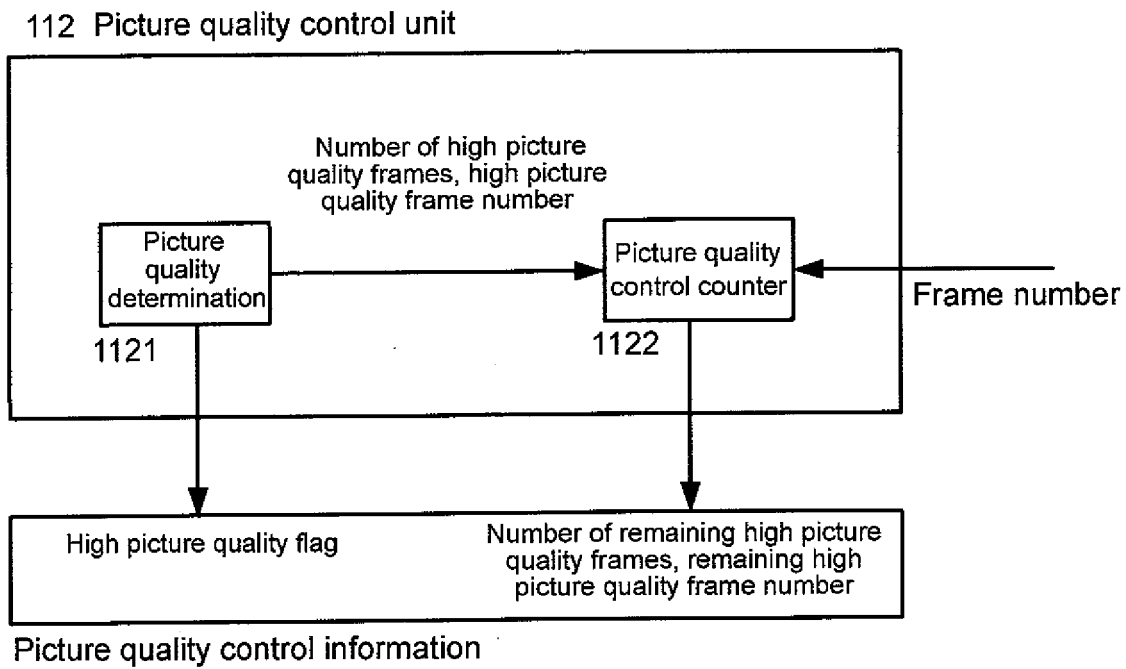
[Fig. 3]



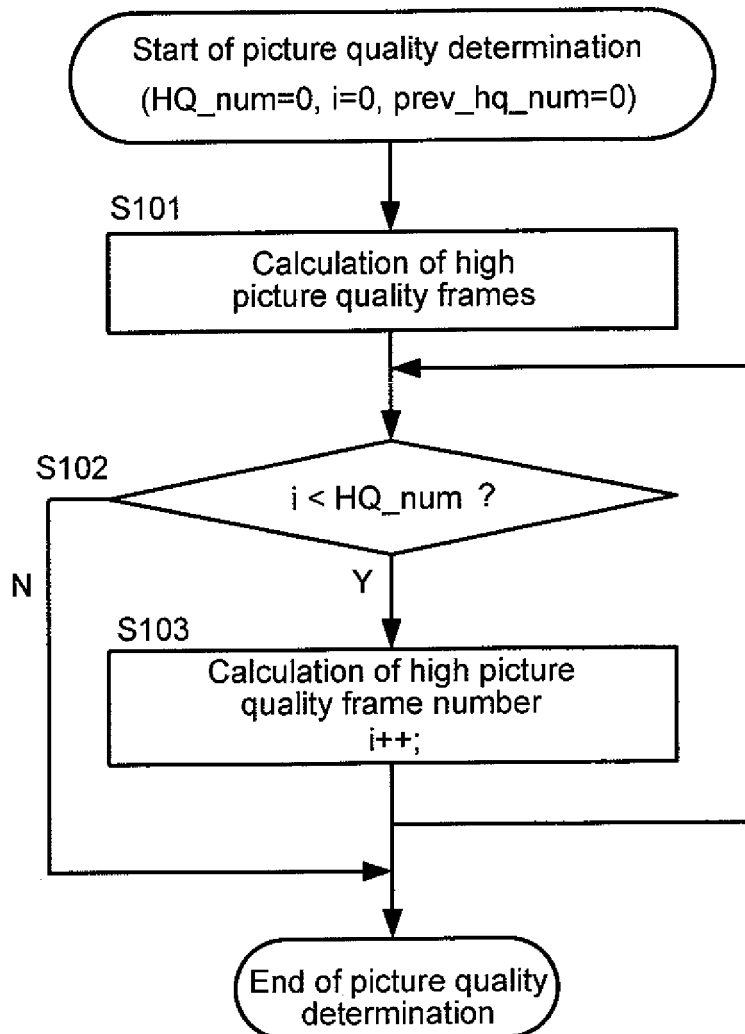
[Fig. 4]



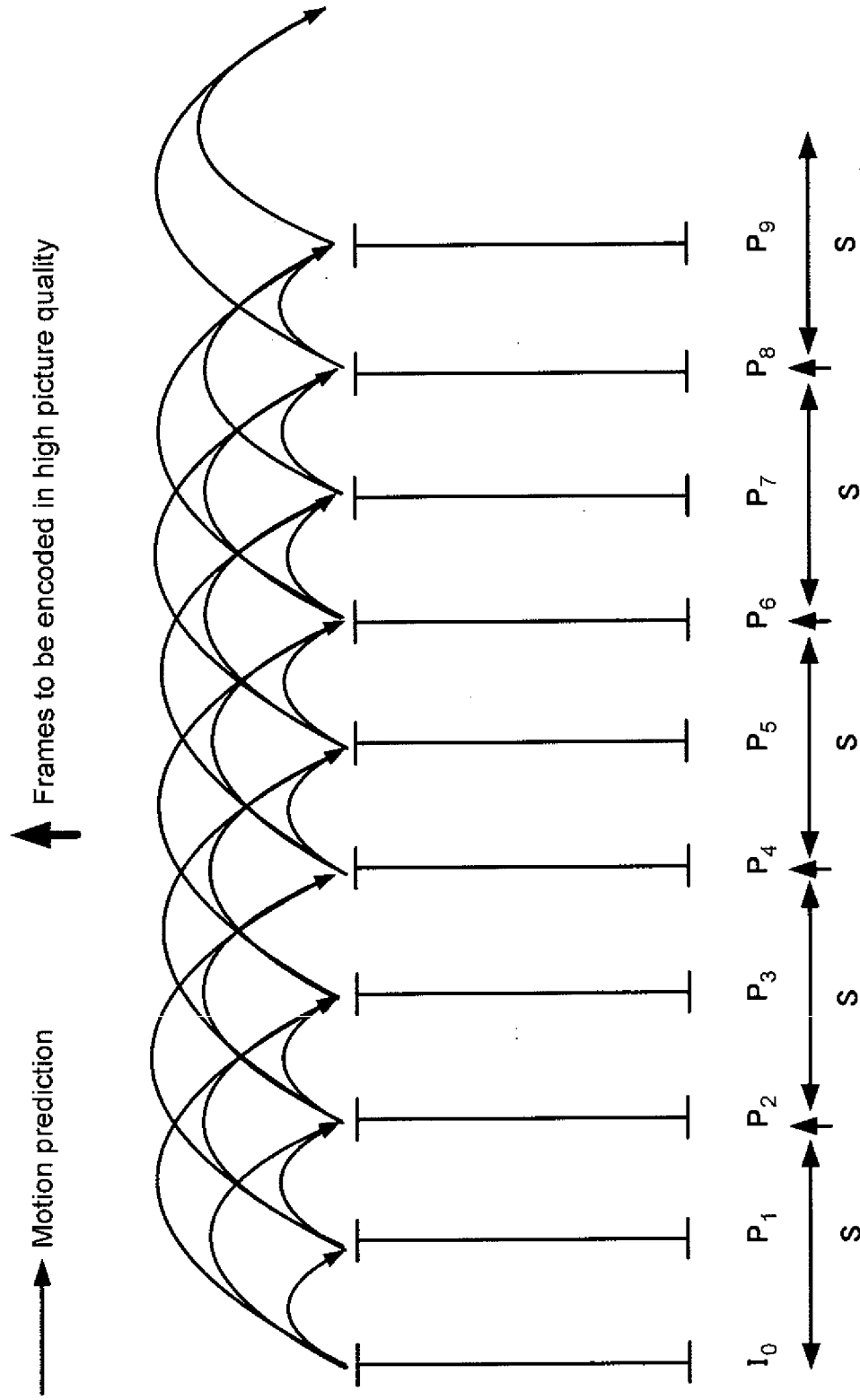
[Fig. 5]



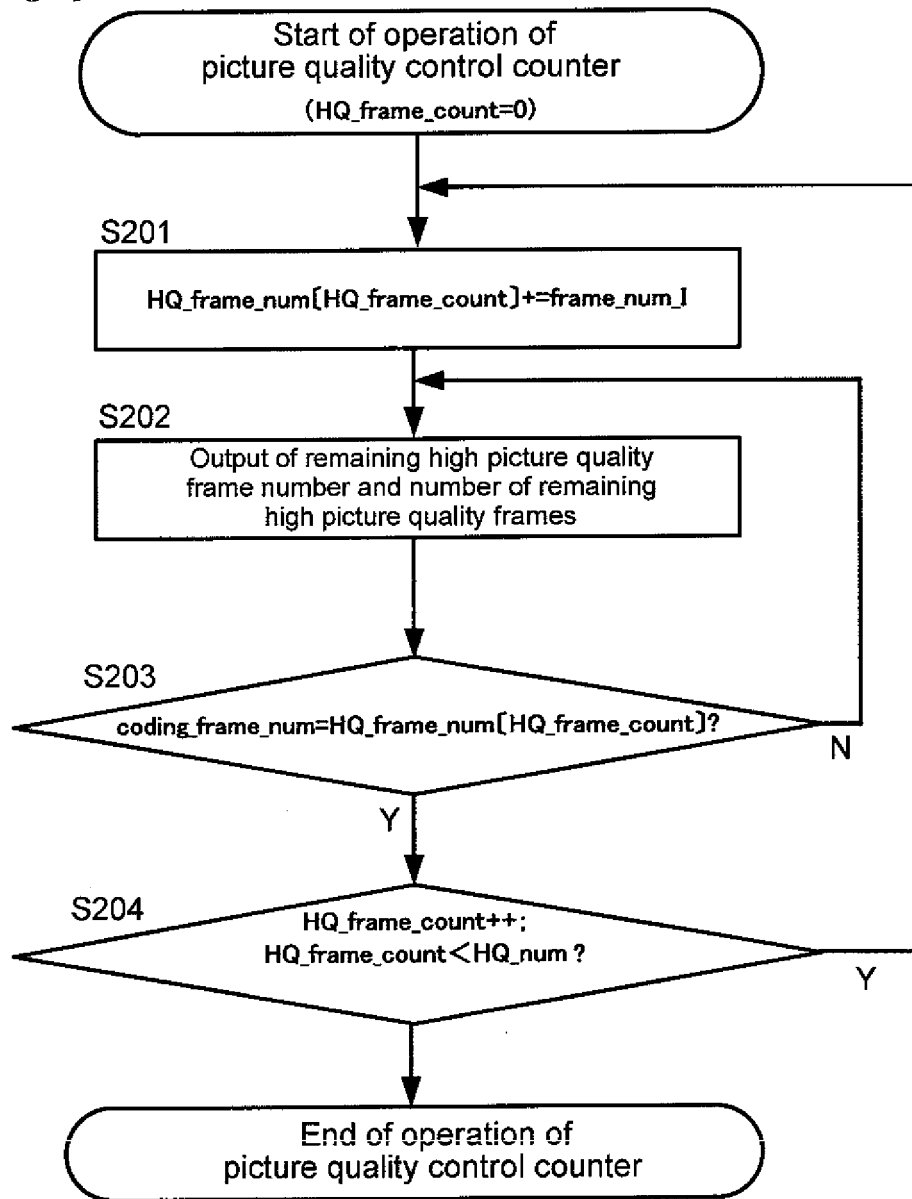
[Fig. 6]



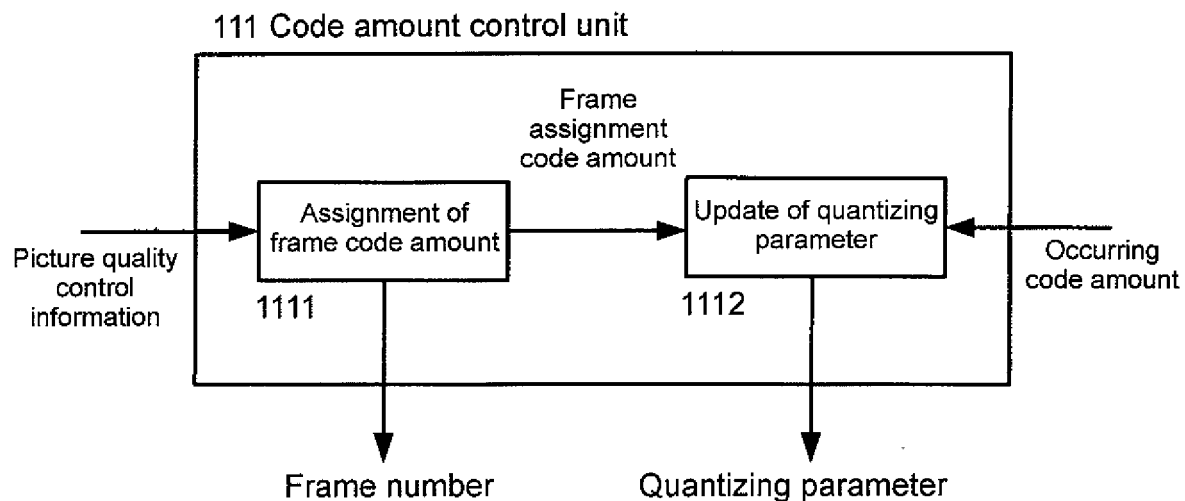
[Fig. 7]



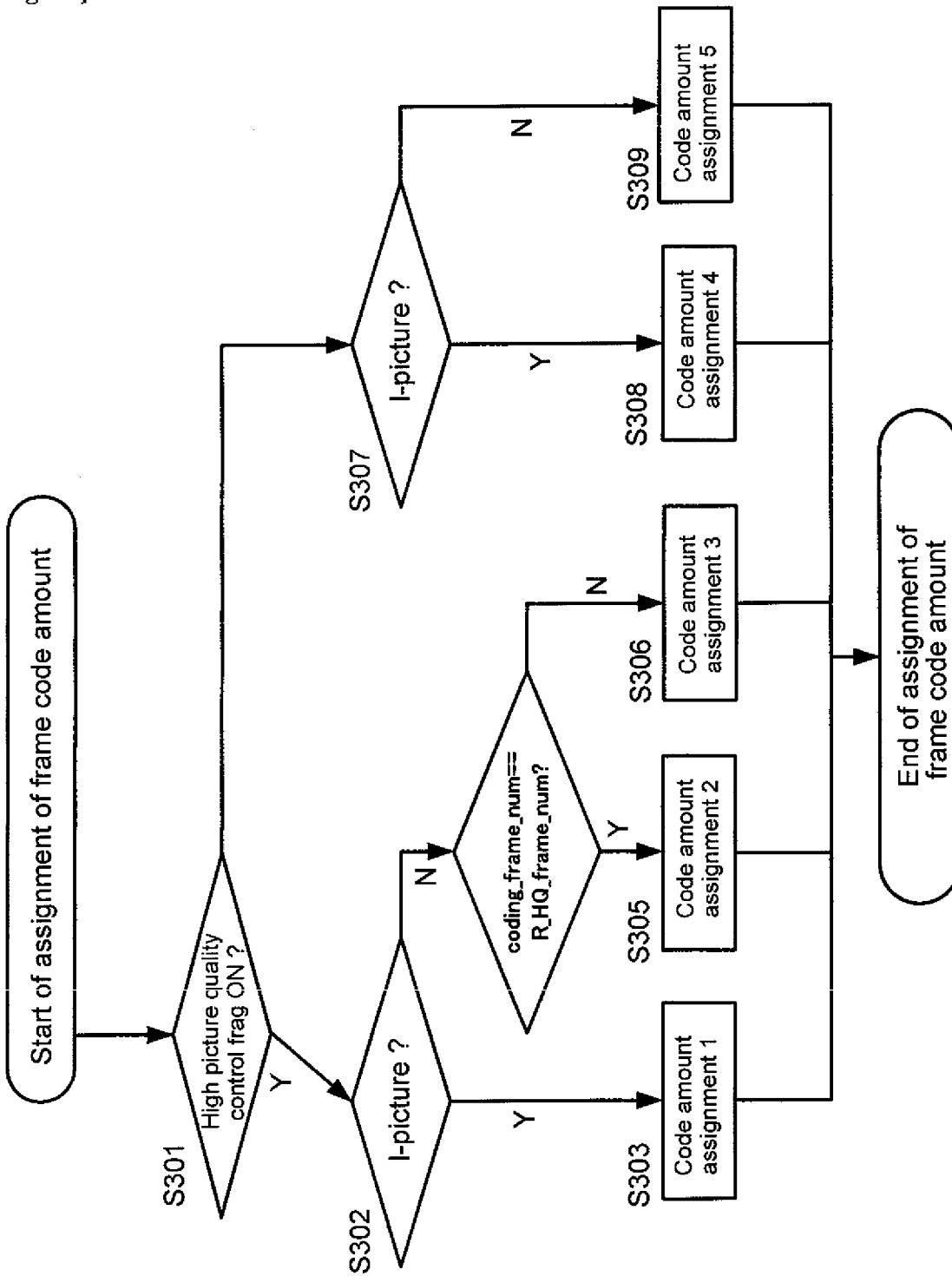
[Fig. 8]



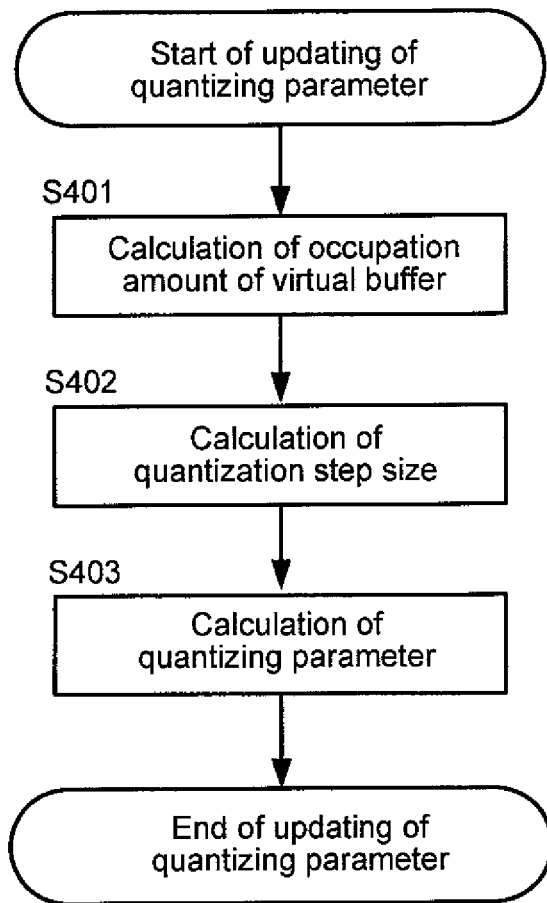
[Fig. 9]



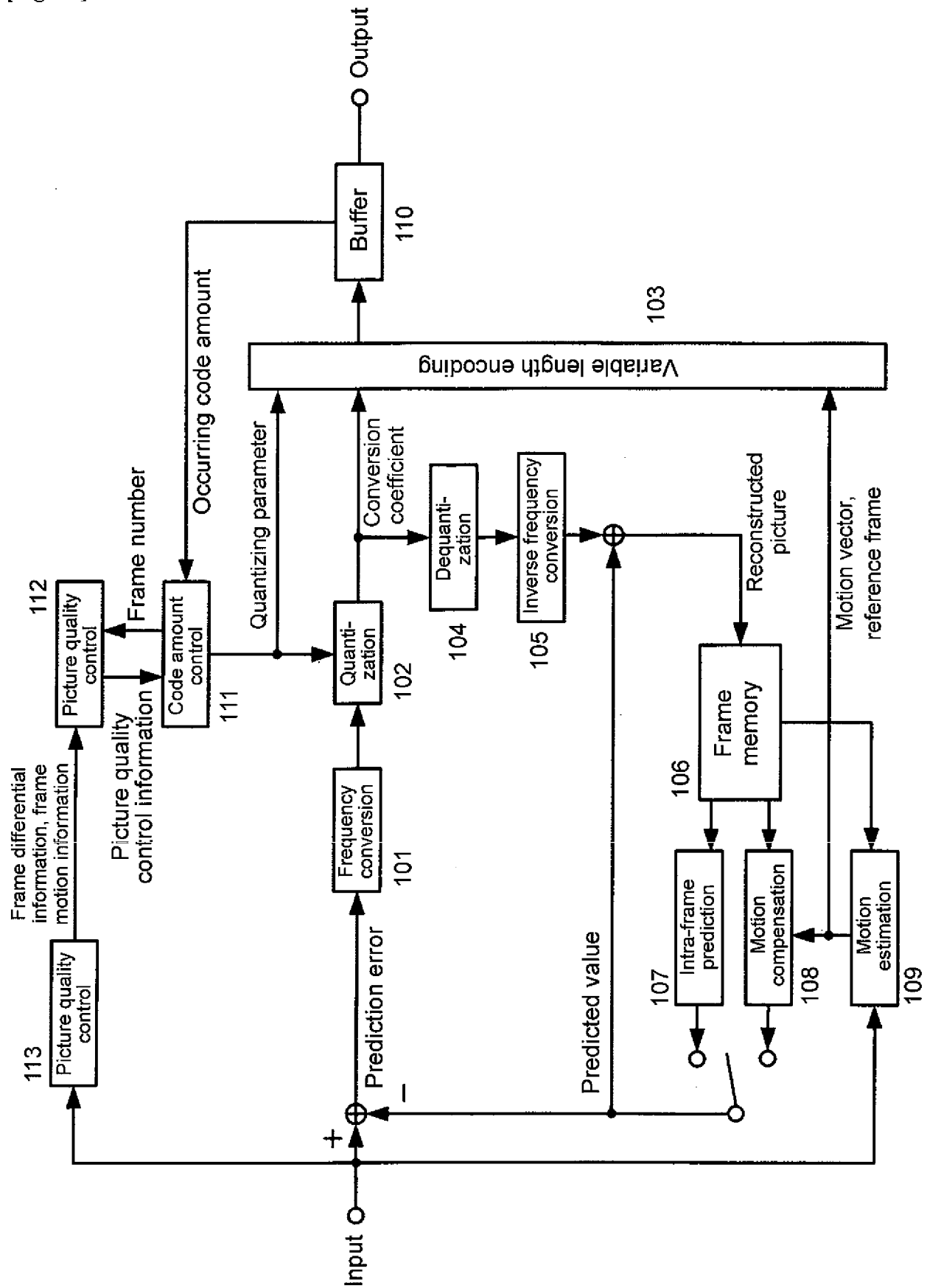
[Fig. 10]



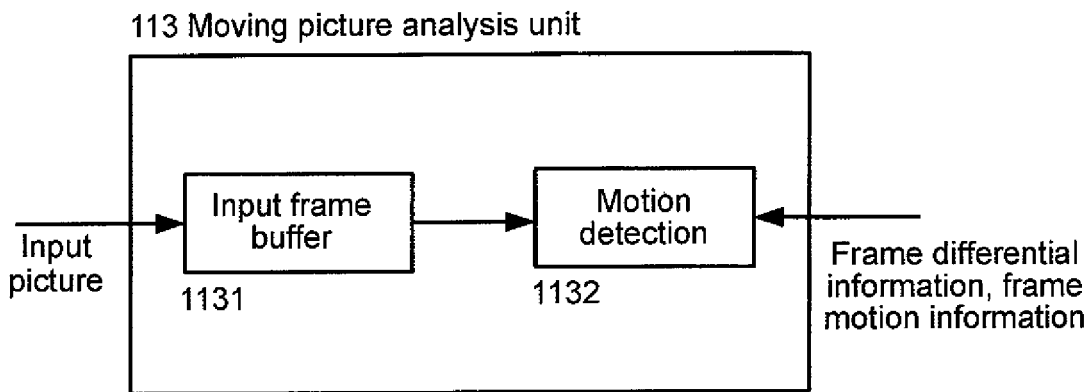
[Fig. 11]



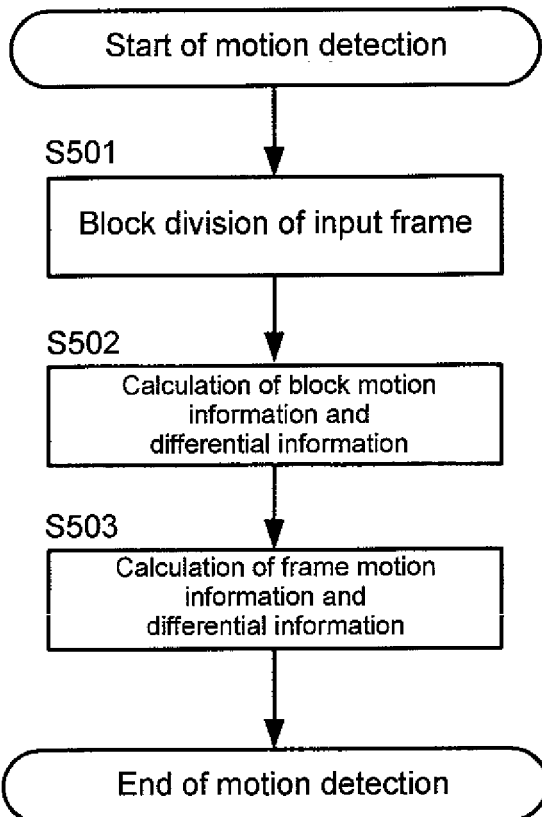
[Fig. 12]



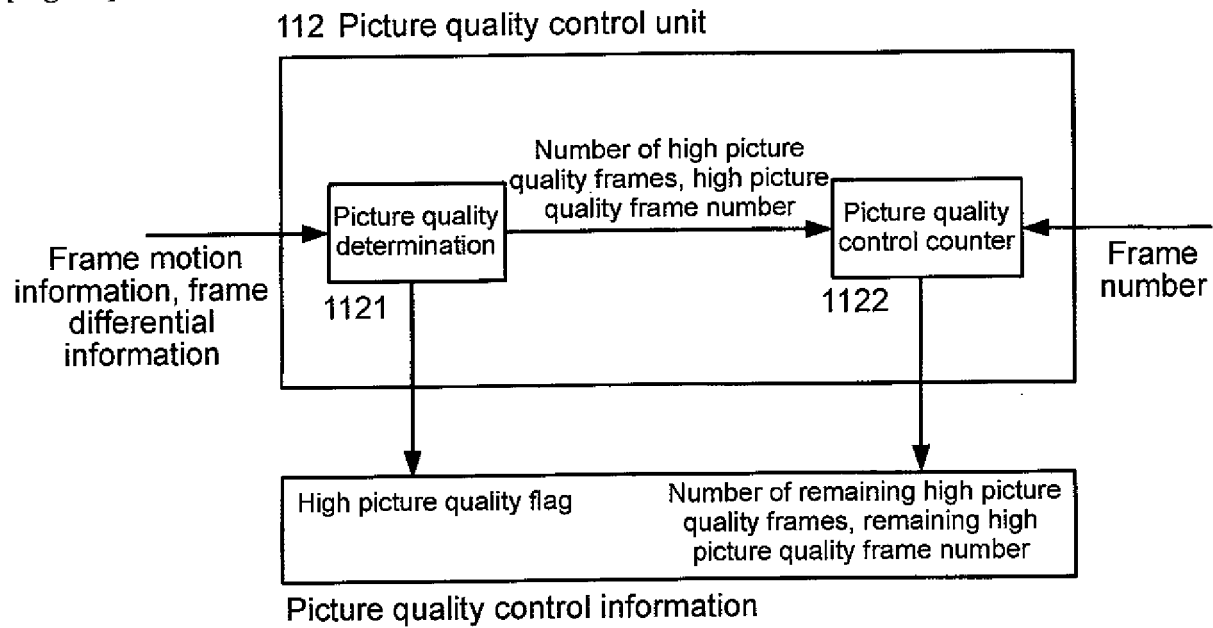
[Fig. 13]



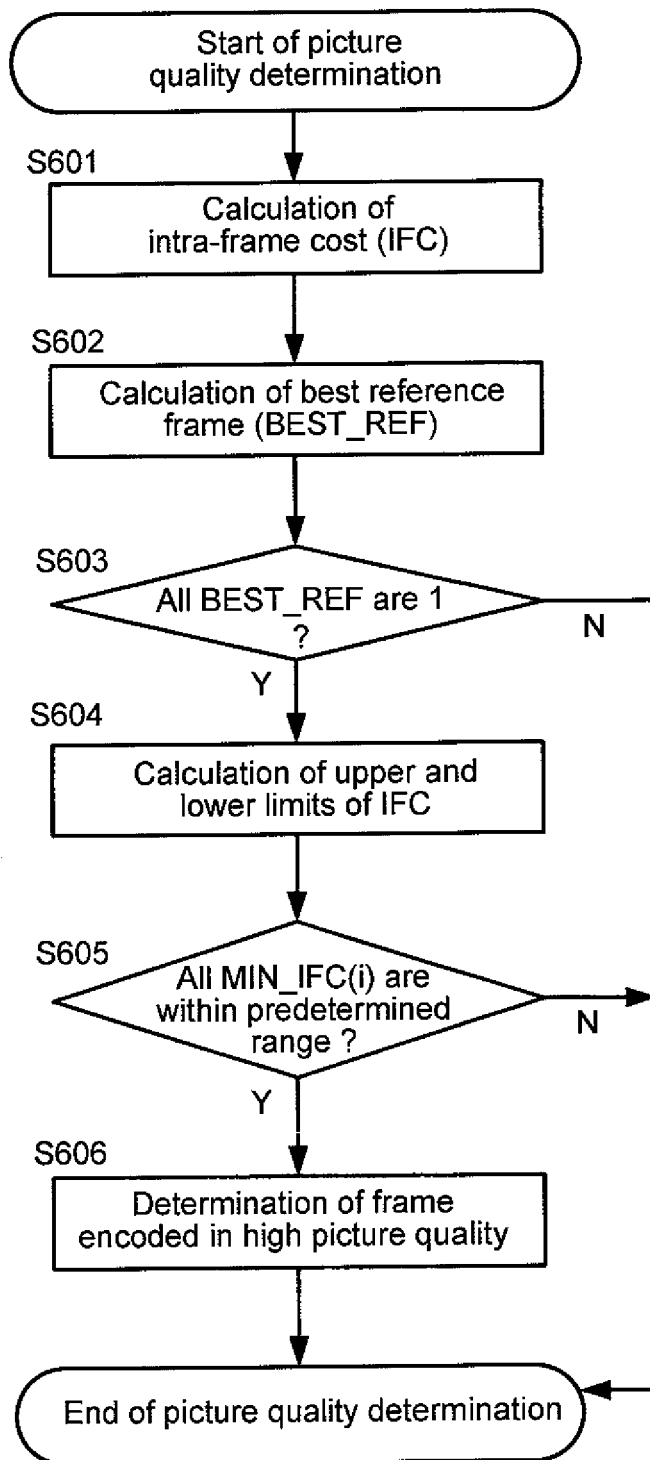
[Fig. 14]



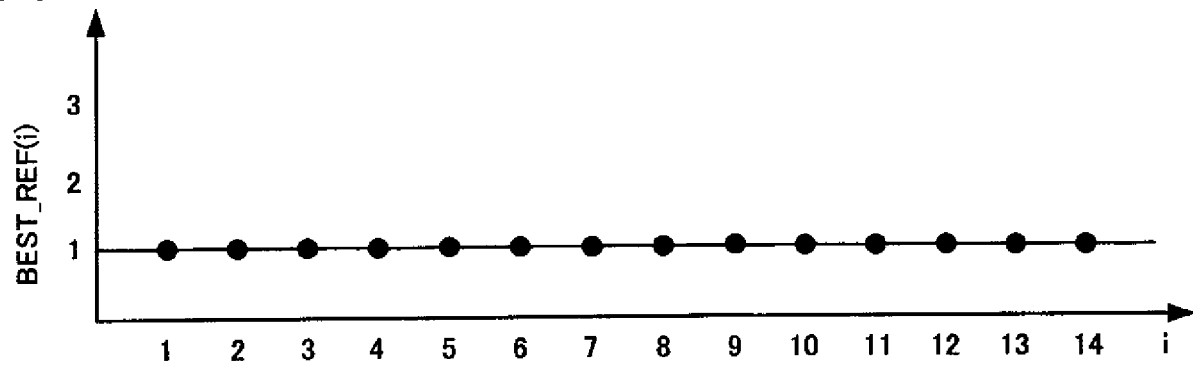
[Fig. 15]



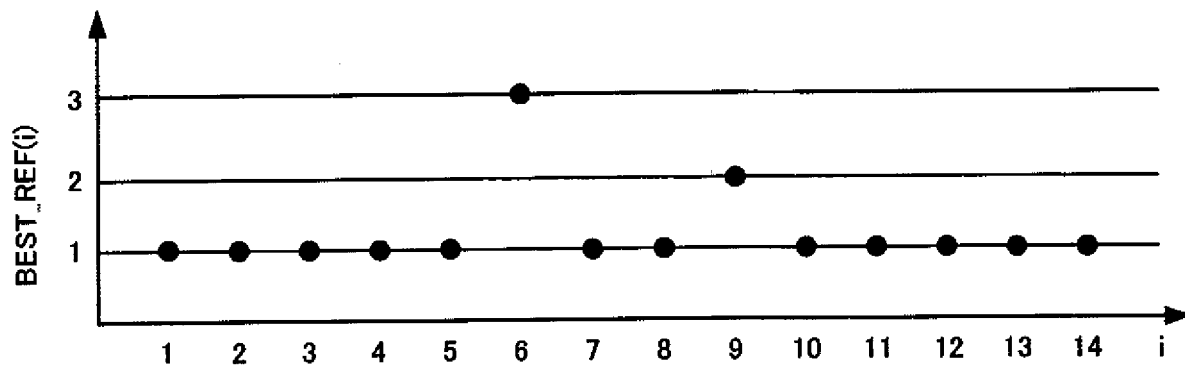
[Fig. 16]



[Fig. 17]

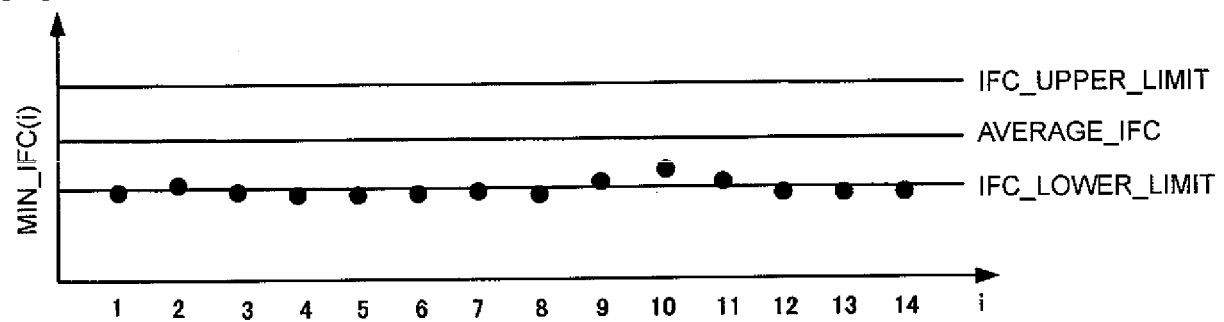


(a) Continuous scene

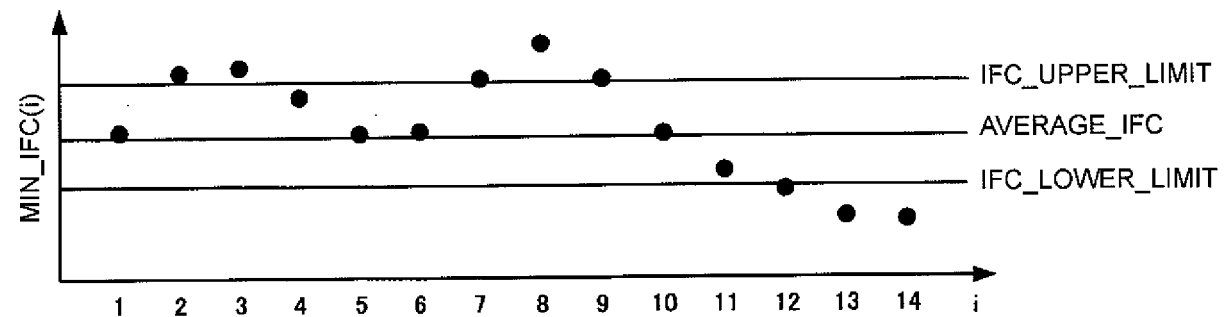


(b) Discontinuous scene

[Fig. 18]

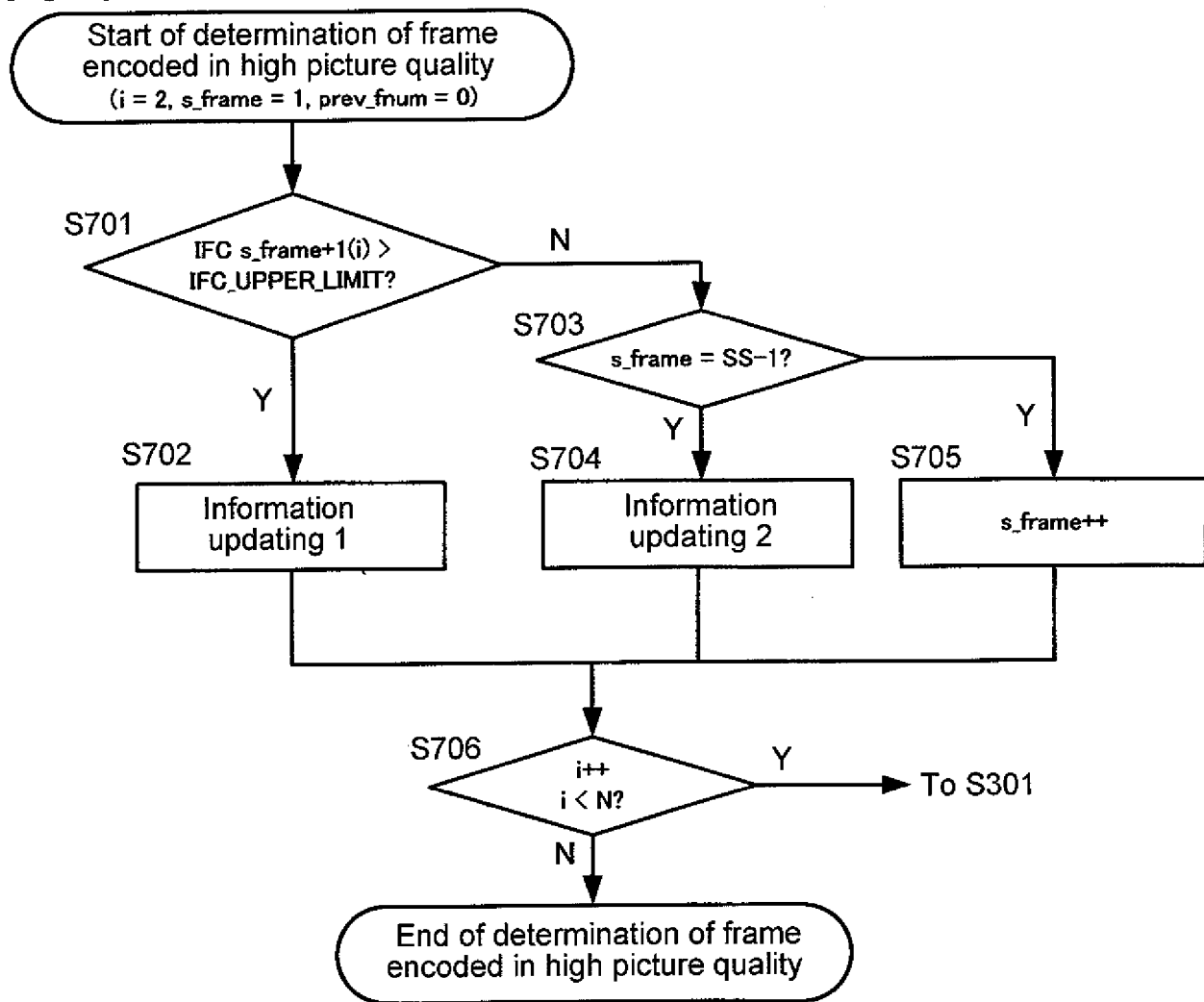


(a) Difficulty of inter-frame prediction - Stable

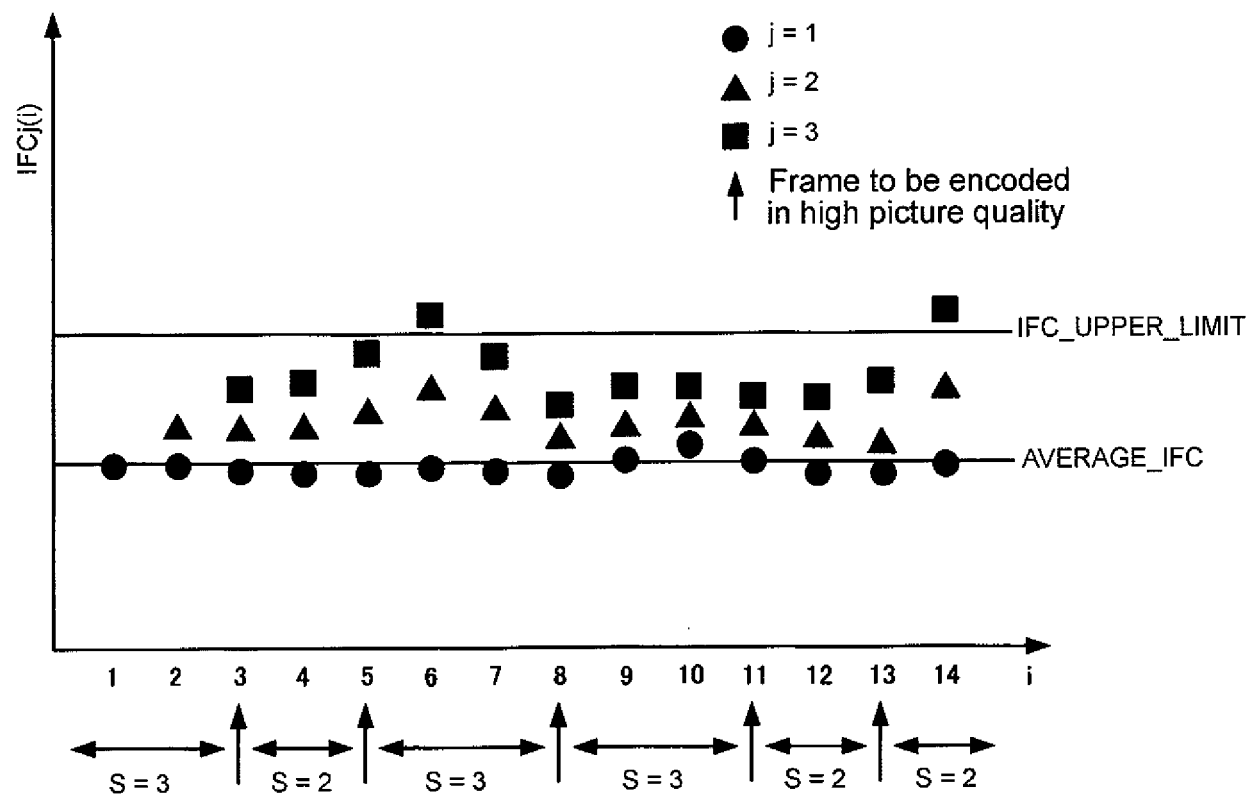


(b) Difficulty of inter-frame prediction - Unstable

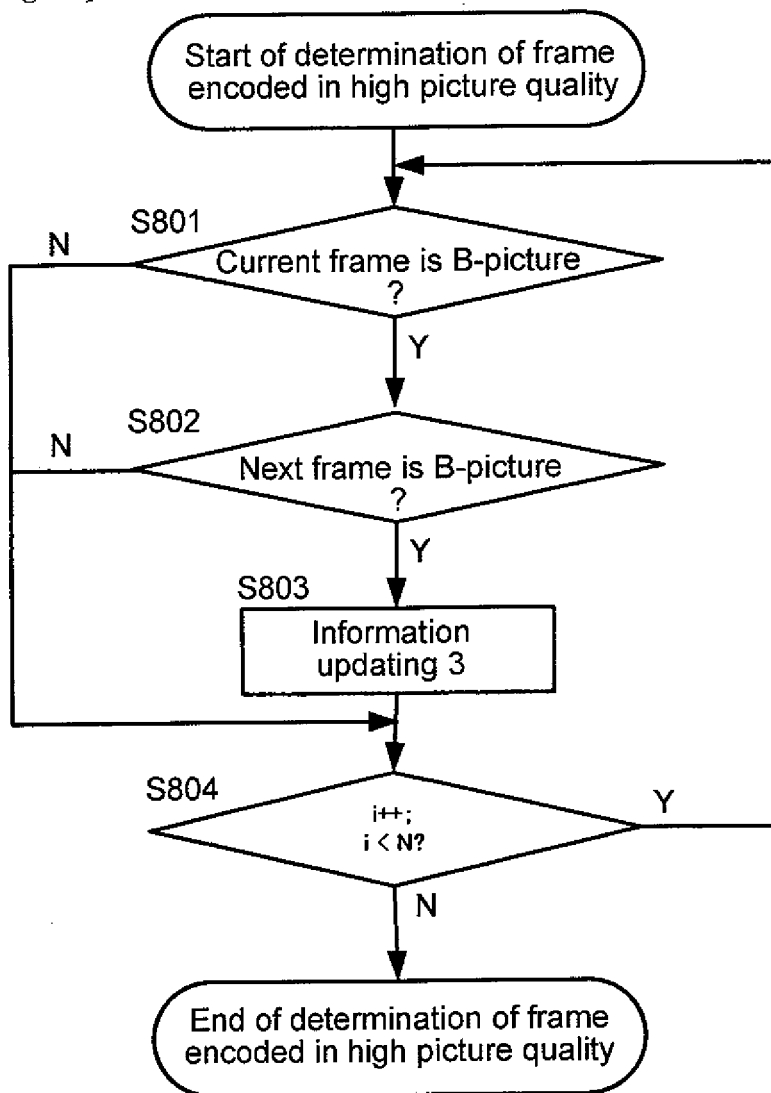
[Fig. 19]



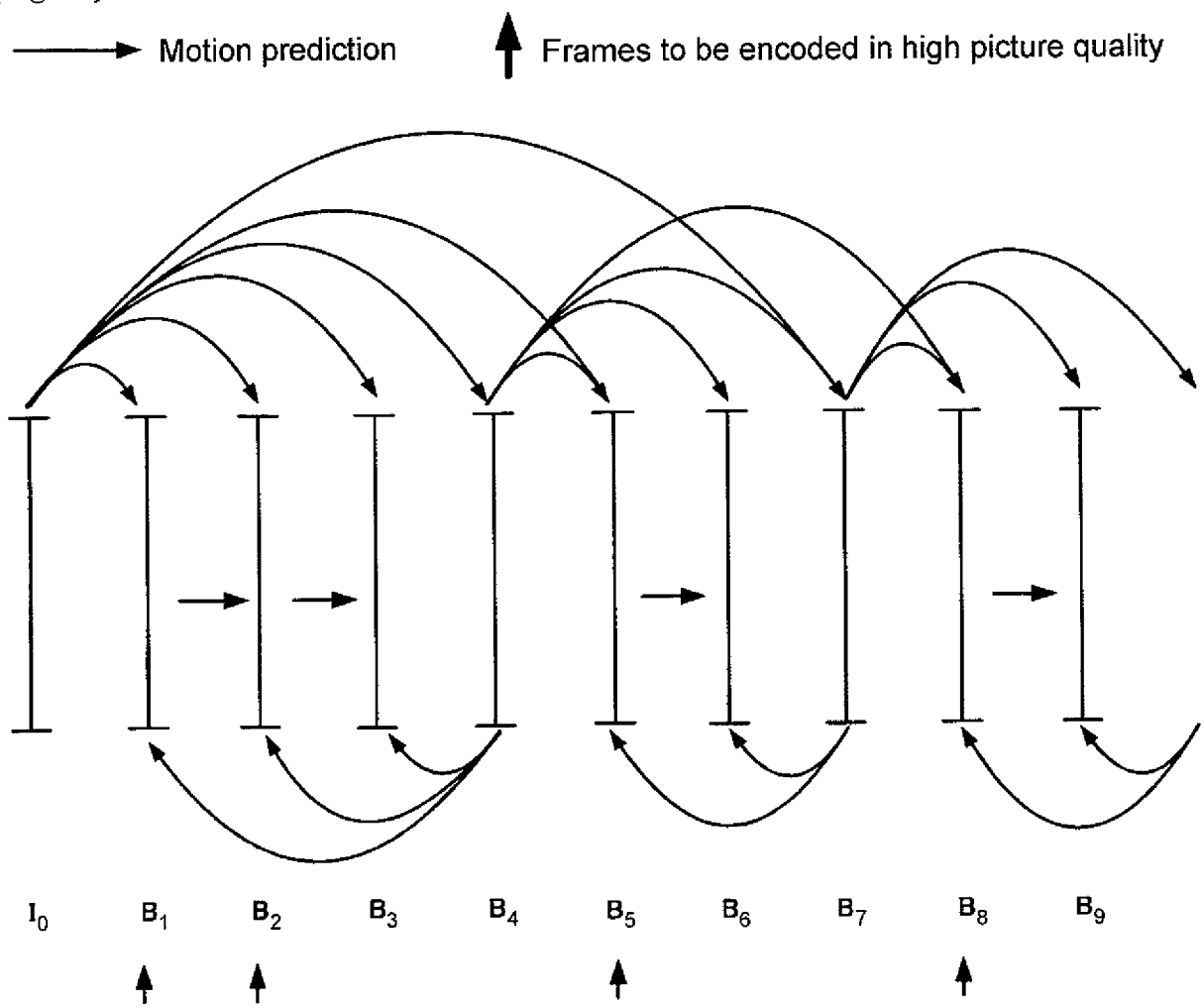
[Fig. 20]



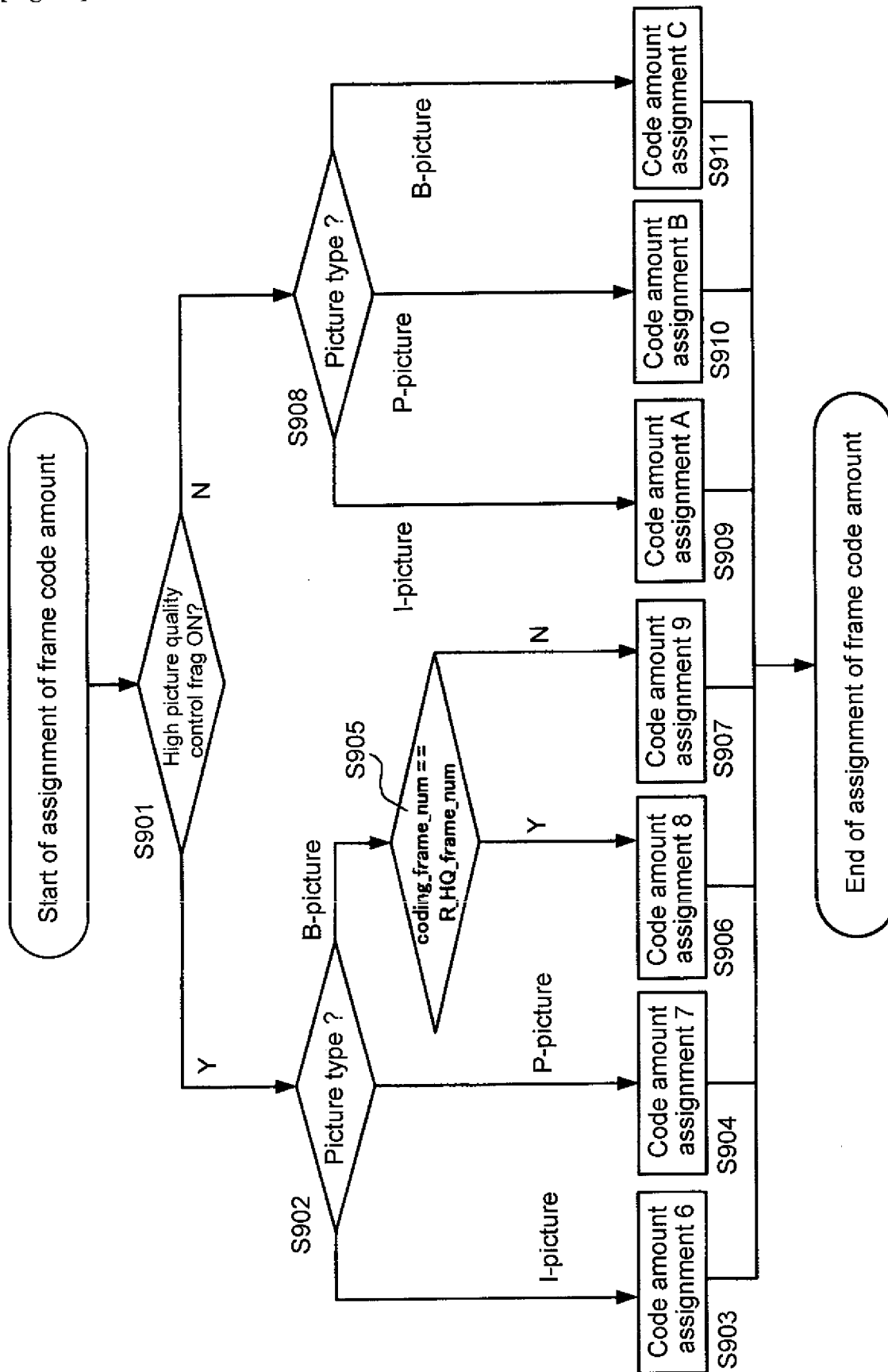
[Fig. 21]



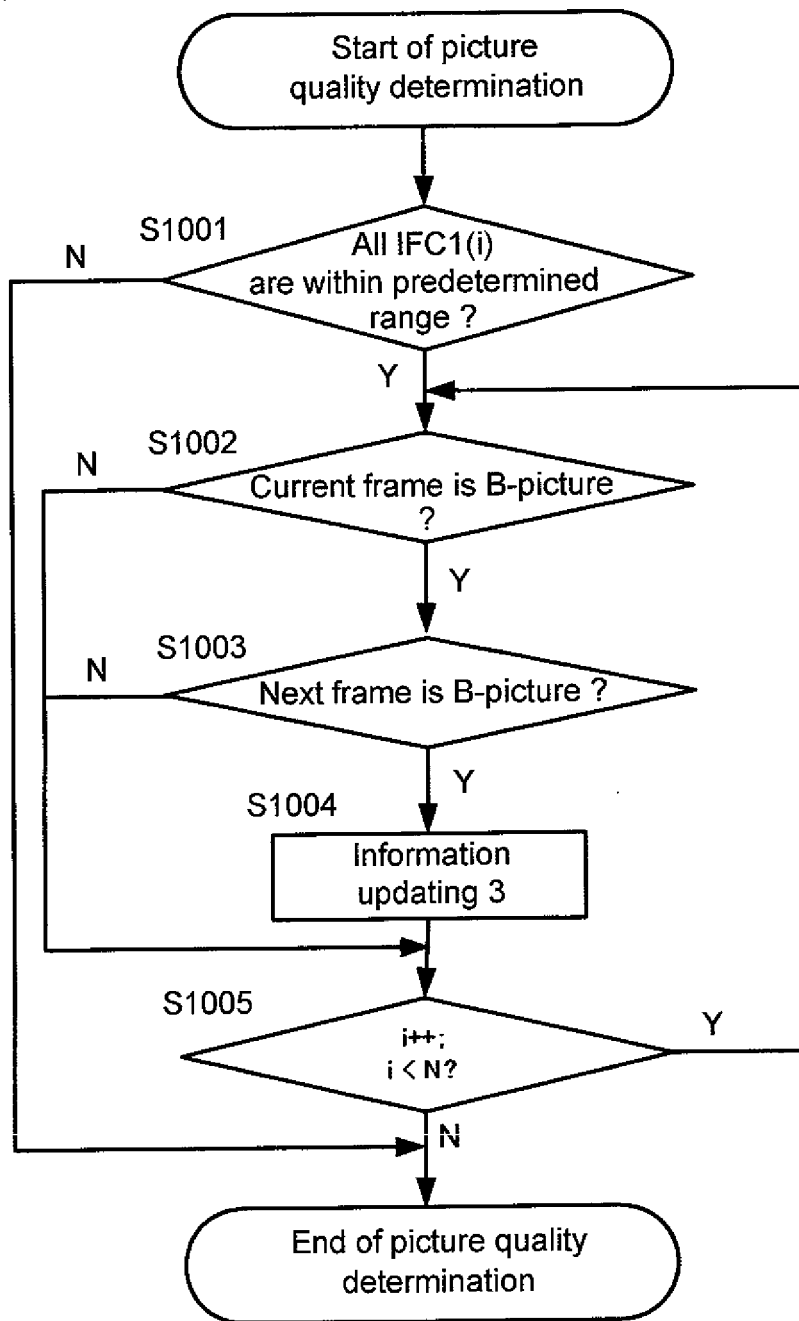
[Fig. 22]



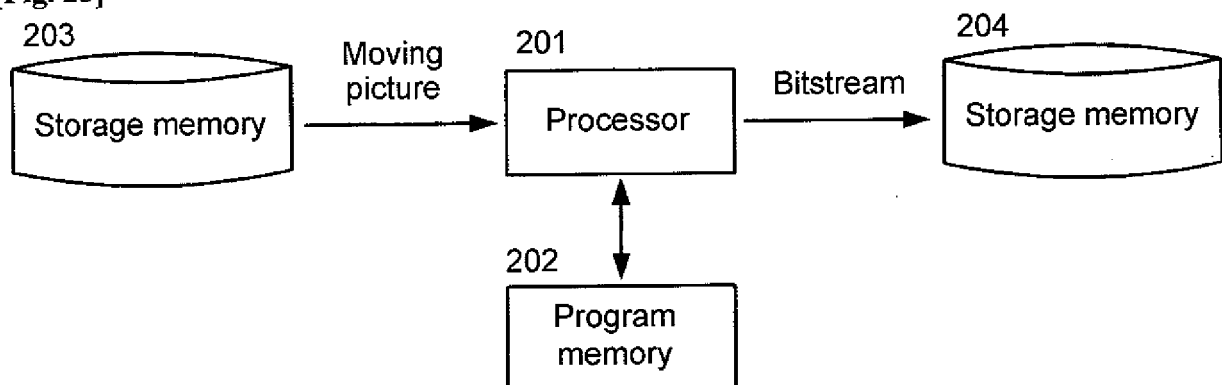
[Fig. 23]



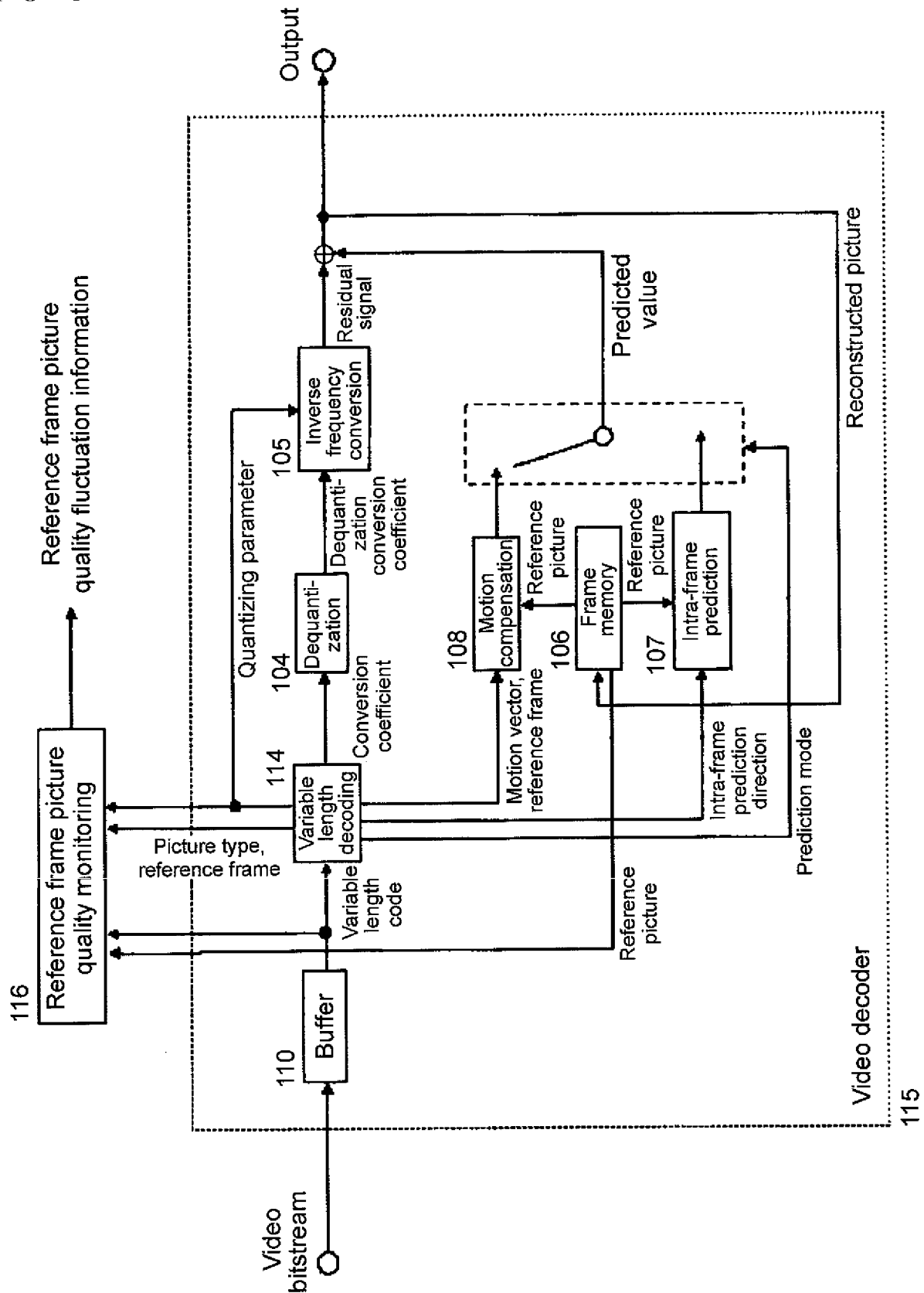
[Fig. 24]



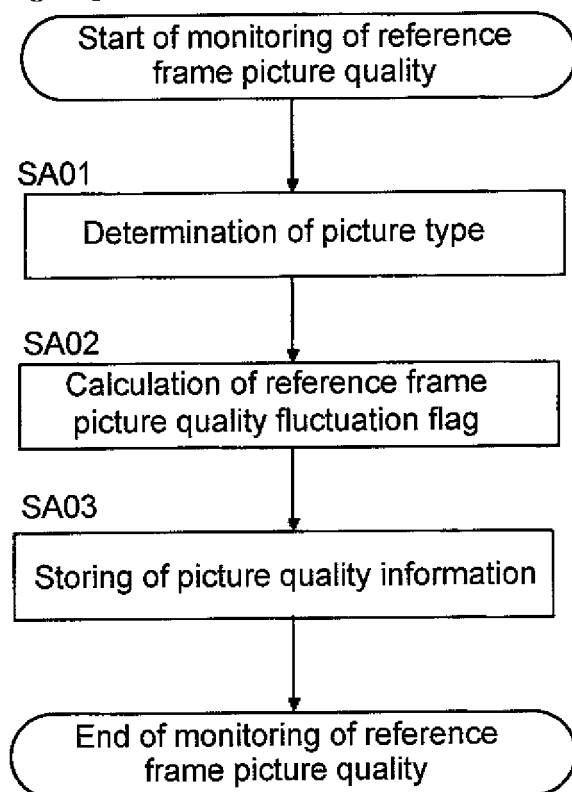
[Fig. 25]



[Fig. 26]



[Fig. 27]



[Document Name] ABSTRACT

[Abstract]

[Problem] To provide a moving picture encoding technique of encoding a moving picture in a high picture quality by effectively using the multi-frame prediction.

- 5 [Solving Means] In the moving picture compression using the multi-frame motion prediction, not the picture type and the complexity of each picture that is finally encoded are simply used, but code amount control is performed so as to improve the effects of the motion prediction of the whole scene by encoding a frame having high priority as a reference frame in a high picture quality in consideration of the relationship between the subject frame to be encoded and the
- 10 reference frame in the multi-frame motion prediction.

[Representative Drawing] Fig. 7